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Eye Screening in U.S. Adults with Diabetes: Examination of Trends, Racial and Ethnic Differences, and Contribution of Medicaid Expansion, MEPS 2010-2017

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EYE SCREENING IN U.S. ADULTS WITH DIABETES: EXAMINATION OF TRENDS, RACIAL AND ETHNIC DIFFERENCES, AND CONTRIBUTION OF MEDICAID EXPANSION, MEPS 2010-2017

by

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(Under the Direction of Yelena N. Tarasenko)

ABSTRACT

Diabetic retinopathy (DR) is a prevalent cause of vision impairment and blindness among adults in the United States. Early diagnosis of DR through dilated eye examinations can reduce the risk of vision impairment or loss. Differences in eye examination rates by race and ethnicity have been suggested by prior studies emphasizing importance of increasing insurance coverage and access to care among minority populations. The Affordable Care Act aimed to expand health insurance coverage and improve access to care. This study examined trends overall and by race and ethnicity in eye examination rates and the contribution of Medicaid expansion on changes in eye examination rates among U.S. adults with diabetes living below 138% of the federal poverty level (FPL). This research utilized data from the 2010-2017 Medical Expenditure Panel Survey. Univariate and multivariable logistic regression models with post-estimation commands were fit to assess changes in eye examination rates overall, by race and ethnicity, and by residence in a state that expanded or did not expand Medicaid, while controlling for predisposing, enabling, and need factors, as conceptualized by the Andersen Healthcare Utilization model. Eye examination rates did not significantly change among non-Hispanic whites, non-Hispanic blacks, and Hispanics from 2010-2017. The fully adjusted model revealed no significant differences in eye examination rates between the three racial and ethnic subgroups and in individuals with diabetes living below 138% of the FPL in expansion vs non-expansion states. Between 2010 and 2017, no significant improvements in eye examination were noted among non-Hispanic whites, non-Hispanic blacks, and Hispanics, and Medicaid expansion was not associated with changes in eye examination rates. Research on public health interventions targeting other factors that influence eye screening is warranted as expanding access to insurance coverage alone did not appear to translate into improvements in eye examinations.

INDEX WORDS: Diabetic retinopathy, Dilated eye examination, Racial and ethnic disparities, Affordable Care Act, Medicaid expansion, MEPS.

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DEDICATION

I dedicate my dissertation to my eight nieces, Charniqua, Kamary, Maia, Eden, Lyric, Emilia, Londyn, and Lola. You all bring me so much joy and continuously inspire me to be the best version of myself. My legacy is dedicated to you. I also dedicate my dissertation to my grandmother, Ethel Katherine Lewis, who sadly passed away shortly after my defense. One of my biggest supporters and always present to see my accomplishments, I am grateful that she was able to see me complete this.

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CHAPTER 1-INTRODUCTION

Background

The global diabetes prevalence in adults aged 20-79 years is estimated to be 9.3% in 2019 and is projected to rise to 10.9% by the year 2045 (Saeedi et al., 2019). In 2018, an estimated 34.2 million people of all ages or 10.5% of the United States (U.S.) population had diagnosed diabetes. For U.S. adults 18+ years, the prevalence of diagnosed diabetes in 2018 was 13.0% (34.1 million adults) (Centers for Disease Control and Prevention [CDC], 2020a). The diabetes prevalence is projected to continue to rise over time as the U.S. population grows and ages (American Diabetes Association [ADA], 2018).

Diabetes is a chronic condition characterized by high levels of blood glucose, which is a sugar found in many foods. When food is digested and broken down, glucose is released and absorbed into the intestines where it passes into the bloodstream. Insulin is a hormone made by the pancreas that promotes the absorption of blood glucose into various cells of the body for energy and storage. Diabetes develops when the body is either not able to produce insulin or is not able to use insulin properly (Roglic, 2016). With type 1 diabetes, the immune system destroys the cells in the pancreas that make insulin (National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK], 2017a). As a result, the body cannot make insulin, glucose can no longer get into cells, and blood glucose levels rise above normal (NIDDK, 2017a). Type 1 diabetes most often occurs in children and young adults but can appear at any age. The risk of developing type 1 diabetes may increase in individuals whose parent or sibling have type 1 diabetes (NIDDK, 2017a). Type 2 diabetes is the most common form of diabetes and occurs when the body under-produces insulin or does not use insulin properly (NIDDK, 2017b). As a result, glucose is not absorbed properly leading to high levels of glucose in the blood. Individuals are more likely to develop type 2 diabetes if they are age 45 or older, are African American, Alaska Native, American Indian, Asian American, Hispanic/Latino, Native Hawaiian, or Pacific Islander, have a family history of diabetes, live a sedentary lifestyle, are overweight or obese, or have high blood pressure, low high-density lipoprotein cholesterol, high triglycerides, or depression (NIDDK, 2016).

The continuous presence of excess blood glucose can lead to negative changes in the blood vessels, and people with diabetes often develop diverse vascular-related complications that can drastically reduce the quality of life (Boyle et al., 2010). A microvascular complication of diabetes, diabetic retinopathy is the most prevalent cause of vision impairment and blindness among working-age adults (i.e., those aged 20-74 years) in the U.S. and the fifth most common cause of vision impairment and blindness in the world (CDC, 2018; Cheung et al., 2010; Leasher et al., 2016; Mohamed et al., 2007). Diabetic retinopathy exists in several stages including early and severe non-proliferative diabetic retinopathy (NPDR), proliferative diabetic retinopathy (PDR), and diabetic macular edema (DME) (Khandekar, 2012). Individuals with NPDR may not exhibit any symptoms; however, those with PDR are at risk for blindness and/or other serious morbidities (Khandekar, 2012). Approximately one in three people with diabetes aged 40 years and above has some sign of the diabetic retinopathy (CDC, 2014; Zhang et al., 2010). Progression from NPDR to PDR may occur over years of time. The Wisconsin Epidemiologic Study of Diabetic Retinopathy (WESDR) found the incidence of PDR had increased from 0% during the first 5 years of having diabetes to 27.9% during years 13–14 of diabetes and remained stable after 15 years (Klein et al., 1984). Compared to individuals without diabetic retinopathy, those with diabetic retinopathy may experience a lower quality of life. A study performed in a diabetes patient population in India found that the quality of life was significantly lower in patients with diabetic retinopathy when compared with those without diabetic retinopathy with maximum effect seen on general health, general vision and mental health (Pereira et al., 2017). Furthermore, as the severity and duration of retinopathy increased, the quality of life decreased (Pereira et al., 2017).

One way to reduce the risk of severe vision impairment or loss resulting from diabetic retinopathy is through screening in the form of dilated eye examinations (ADA, 2019). Early detection of diabetic retinopathy through screening can reduce severe vision loss by up to 94% (Fathy, Patel, Sternberg, & Kohanim, 2016). In identifying the condition during screening, timely and appropriate vision care (e.g., laser treatment, medications, and/or surgery) can prevent or delay the onset of ocular morbidity, visual impairment, and blindness associated with diabetic retinopathy (Khandekar, 2012; Paz et al., 2006). The ADA (2019) and the American Academy of Ophthalmology (2019) recommend people with type 1 diabetes receive annual eye examinations beginning 5 years after the onset of the disease, whereas people with type 2 diabetes have an eye examination at onset of the disease and annually thereafter. However, in 2016, only 62.2% of adults with diabetes reported having an annual screening for diabetic retinopathy (CDC, 2020b).

Problem Statement

Diabetic retinopathy has been shown to disproportionately affect racial and ethnic minority populations. For example, non-Hispanic blacks and Hispanics are more likely to have diabetic retinopathy compared with non-Hispanic whites (Carter et al., 1996; Golden et al., 2012; Osborn et al., 2013). A study based on data from the 1988-1994 National Health and Nutrition Examination Survey (NHANES) found in adults aged 40 years and older, the presence of any diabetic retinopathy was 46% higher in non-Hispanic blacks and 84% higher in Mexican Americans than non-Hispanic whites (Harris et al., 1998). Similarly, in a study based on data from the Veterans Affairs Diabetes Trial, macular edema was significantly more prevalent in Hispanics (18%) and non-Hispanic blacks (15.6%) than in non-Hispanic whites (6.3%) (Emanuele et al., 2009). Using 2005-2008 NHANES, a study of adults >=40 years of age with diabetes found non-Hispanic blacks and Hispanic individuals had a higher crude prevalence of diabetic retinopathy than non-Hispanic whites (38.8%, 34.0%, respectively, vs 26.4%) and a higher crude prevalence of vision-threatening diabetic retinopathy, defined as the presence of severe NPDR, PDR, or DME (9.3% and 7.3% respectively, vs 3.2%) (Zhang et al., 2010). In a study of 312 people who visited a Model Demonstration Unit of the Washington University Diabetes Research and Training Center, African Americans with type 1 diabetes were 1.86 times more likely to develop PDR compared to whites (Arfken et al., 1998).

Additionally, some studies report differences in eye examination rates among racial and ethnic groups (Chen et al., 2014; Lu et al., 2016; Shi et al., 2014; Tran et al., 2017). A study based on the 2002-2013 Medical Expenditure Panel Survey (MEPS) data showed respondents of Asian and Hispanic ethnicity had a 49% and 15%, respectively, lower likelihood of ever having received a dilated eye examination when compared to non-Hispanic/non-Asian whites (Tran et al., 2017). Lu et al., surveyed 101 African American or Hispanic diabetic patients from a safety-net clinic in Los Angeles to examine perceived barriers to screening (2016). Compared with Hispanic patients, African American patients were screened 50% less often in the previous year, despite reporting similar barriers to diabetic retinopathy screening (Lu et al., 2016).

Previous studies have identified various barriers to obtaining eye examinations with lack of health insurance being identified as the most common barrier across studies (Ellish et al., 2007; Lu et al., 2016; Owsley et al., 2006; Paz et al., 2006; Shi et al., 2014; Walker et al., 1997). Racial and ethnic minority populations are less likely to be insured compared to whites (Andrulis et al., 2010; Rowland & Shartzer, 2008; Office of the Assistant Secretary for Planning and Evaluation [ASPE], 2012). Uninsured individuals are more likely to have unmet medical needs and fare worse in health outcomes compared to insured individuals (Clemans-Cope et al., & Blavin, 2012; Hadley, 2003; Institute of Medicine, 2001).

The Affordable Care Act (ACA) aimed to extend health insurance coverage predominantly through the following initiatives: expansion of Medicaid eligibility to nearly all adults with incomes up to 138 percent of the federal poverty level (FPL) (previous eligibility was limited to specific low-income groups, such as the elderly, people with disabilities, children, pregnant women, and some parents; the eligibility varies from state to state); establishment of health insurance exchanges for small employers (e.g., ≥50 employees) and individuals purchasing private coverage with subsidies for individuals with incomes at 138-400 percent of the FPL; and requirement that US citizens and legal residents have qualifying health coverage or pay a tax penalty (Clemans-Cope et al., 2012; The Henry J. Kaiser Family Foundation [KFF], 2012, 2020).

Recent studies have demonstrated that racial and ethnic disparities in insurance coverage and access to care have been reduced since ACA implementation (Buchmueller et al., 2016; Chen et al., 2016; Monnette et al., 2019; ASPE, 2016). However, further research is warranted on whether increased insurance coverage translates into improved health practices and outcomes.

Purpose

The purpose of this study was to examine trends in eye examination rates among U.S. adults with diabetes overall and by race and ethnicity and to examine the contribution of the ACA Medicaid expansion to changes in eye examination rates between 2010-2017.

Research Questions

RQ1: Are there racial and ethnic disparities in eye examination rates among U.S. adults (age≥18 years) with diabetes across 2010-2017?

RQ2: Is ACA Medicaid expansion associated with changes in eye examination rates among U.S. adults with diabetes living below 138% of the federal poverty level (FPL)?

Significance

Racial and ethnic disparities in utilization of health care services and health outcomes have been well-documented in the U.S. Minority populations encompass smaller groups of people who may be discriminated against in society and differ from the majority population by race, ethnicity, religion, language or political affiliation (Humes et al., 2011). In a country that is predominantly white, racial minority populations in the U.S. include blacks or African Americans, Native Americans and Alaskan Natives, Asian Americans, and Native Hawaiian and Other Pacific Islanders. The largest minority ethnic group in the U.S. is Hispanics and Latinos; however, additional ethnic groups such as Jews and Arabs are also present in the U.S (Humes et al., 2011). The overarching goals of the Healthy People 2020 was to eliminate disparities, achieve health equity, and improve health for all groups (Office of Disease Prevention and Health Promotion [ODPHP], 2020a). However, achieving such goals requires a multifaceted approach that addresses individual-, sociocultural-, environmental-, and system-level factors. Through expanding access to insurance coverage, improving health care delivery, and reducing costs associated with care, the ACA aimed to address system-level barriers to care.

There are varied reports in the literature regarding whether ACA implementation translates to improved health practices, particularly for preventive care use (Adams et al., 2018; Agirdas & Holding, 2018; Hong et al., 2017; Lee et al., 2019; Lau et al., 2014). A quasi-experimental study of Medical Expenditure Panel Survey (MEPS) data that examined whether ACA was associated with increased preventive care service use among privately insured adults (aged 18-64 years) found ACA implementation was associated with increases in routine check-ups and influenza vaccinations among those privately insured compared to those without insurance (Hong, et al., 2017). However, the ACA was not associated with changes in blood pressure check, cholesterol check and cancer screenings (pap smear test, mammography, and colorectal cancer screening) (Hong et al., 2017). A similar quasi-experimental study of MEPS data examined whether ACA's free preventive care benefits were associated with a reduction in racial and ethnic disparities in the utilization of preventive care use. This study found that privately insured Hispanics and privately insured Blacks had an increased probability of obtaining a colonoscopy and mammogram compared to non-Hispanic whites on Medicaid. However, this study did not find any significant improvements for any racial or ethnic group for cholesterol screenings or Pap smears (Agirdas & Holding, 2018). Similar findings of ACA being associated with improvements in use of some preventive care services but not others were seen in quasi-experimental studies of U.S. women adult (19-64 years) populations (Lee et al., 2019) and U.S. adolescent (18-25 years) populations (Lau et al., 2019).

Outside of system-level barriers to obtaining eye examinations, many other factors such as lack of knowledge regarding need for eye examination, lack of transportation, or lack of local optometrists or ophthalmologists can influence whether an individual with diabetes obtains an eye examination (Roy, 2004; Walker et al., 1997). These other factors can have a stronger influence on screening behavior than health insurance does; therefore, gaining health insurance through ACA implementation may not translate into increased eye examination rates. The findings of this study will provide evidence on how disparities in eye examination rates have changed over time and the ACA's role in addressing racial and ethnic disparities in eye examination rates.

Definition of Terms

The following terms are used throughout this research:

Diabetes- A metabolic disorder in which the body has high sugar levels for prolonged periods of time. May present in various forms such as type 1 (pancreas produces little or no insulin) or type 2 (pancreas produces insufficient insulin or body does not use insulin properly). (NIDDK, 2017a)

Diabetic retinopathy- A microvascular complication of diabetes that affects the eyes. (Mayo Clinic, 2018)

Non-proliferative diabetic retinopathy (NPDR)- A stage of diabetic retinopathy that is characterized by leaky blood vessels. (Khandekar, 2012)

Proliferative diabetic retinopathy (PDR)- A stage of diabetic retinopathy that is characterized by growth of new blood vessels on the retina. (Khandekar, 2012)

Vision-threatening diabetic retinopathy- Includes severe non-proliferative diabetic retinopathy, proliferative diabetic retinopathy, and diabetic macular edema. (Zhang et al., 2010)

Diabetic macular edema (DME)- May accompany any stage of diabetic retinopathy and is characterized by fluid buildup in the macula which is the part of the retina that controls detailed vision abilities. (Khandekar, 2012)

Vision impairment- Defined as a functional limitation of the eye or eyes that cannot be corrected with standard glasses or contact lenses and reduces a person's ability to function at certain or all tasks. (National Academies of Sciences, Engineering, and Medicine [NASEM], 2016)

Blindness- Defined as a visual acuity worse than 20/400. (NASEM, 2016)

Dilated eye examination- Physical examination of the eyes that involves the administration of eye drops to dilate pupils in order to allow more light into the eye. During eye examination, optometrist/ophthalmologist assess for abnormalities with the anatomy and functioning of the eye(s). (National Eye Institute, 2019)

Racial minority- A group of people from a different race living in a country or area where the majority of people are of a different race. (Pollard & O'Hare, 1999)

Ethnic minority- A group of people from a different nationality or ethnicity living in a country or area where the majority of people are of a different nationality or ethnicity. (Pollard & O'Hare, 1999)

Health disparity- A particular type of health difference that is closely linked with economic, social, or environmental disadvantage. Health disparities adversely affect groups of people who have systematically experienced greater social or economic obstacles to health based on their racial or ethnic group, religion, socioeconomic -status, gender, age, or mental health; cognitive, sensory, or physical disability; sexual orientation or gender identity; geographic location; or other characteristics historically linked to discrimination or exclusion. (ODPHP, 2020a)

Health insurance coverage- Coverage that provides for the payments of benefits as a result of sickness or injury. It includes insurance for losses from accident, medical expense, disability, or accidental death and dismemberment (Caxton, 2017)

Affordable Care Act- Health reform legislation signed into law by President Barack Obama in March 2010 that extended health insurance coverage through the expansion of Medicaid eligibility and through establishment of health insurance exchanges for small employers (e.g., ≥50 employees) and individuals purchasing private coverage (Clemans-Cope, 2012; KFF, 2012, 2020; H.R. 3590, 2010).

Medicaid expansion- Expansion of Medicaid eligibility to nearly all adults with incomes up to 138 percent of the federal poverty level (FPL). Previous eligibility varied from state to state but was limited to specific low-income groups, such as the elderly, people with disabilities, children, pregnant women, and some parents. (KFF, 2012, 2020)

Federal poverty level- Defined as the minimum annual income required to avoid living in poverty in the U.S. (ASPE, 2020)

CHAPTER 2-LITERATURE REVIEW

Chapter 2 provides an extensive review of the literature and research on diabetic retinopathy, eye screening, and the Affordable Care Act. The chapter is divided into sections that include an overview of diabetic retinopathy including disease burden, screening and treatment recommendations and costs, factors influencing screening, conceptual framework, the role of health insurance in addressing racial and ethnic disparities, and an overview of the Affordable Care Act.

Out of all the human senses, vision is the most highly developed. It plays an important role in the way humans interact with the environment around them. It is important for learning skills and devices, moving around, and protecting us from danger (American Academy of Ophthalmology, 1987). Therefore, the loss of vision can greatly impact the affected individuals, as well as their friends and family. The weakening or loss of vision can impair an individuals' ability to completely care for themselves and subsequently, can result in the need for a caretaker. Vision loss can affect many aspects of an individual's life such as the quality of life (QOL), independence, mobility, mental health, cognition, social function, employment, and educational attainment (National Academies of Sciences, Engineering, and Medicine, 2016). In a study using Behavioral Risk Factor Surveillance System (BRFSS) data from 22 states, researchers examined health-related QOL among individuals ages 40 to 64 years by visual impairment status and found the percentage of individuals reporting life dissatisfaction, fair or poor reported health, physical and mental unhealthy days, and days of limited activity increased as the self-reported severity of vision impairment increased (Crews et al., 2016; National Academies of Sciences, Engineering, and Medicine, 2016). Furthermore, QOL was shown to slowly decline with the onset of vision loss and then decreased more quickly as measures of visual field defects increased (Rein et al., 2007).

Vision impairment can create challenges for any individual, and the diabetes population is no exception as individuals with diabetes are susceptible to a plethora of vision-related complications. Not being able to see well can affect various vision-reliant tasks for individuals with diabetes. Tasks required for diabetes management such as self-care (e.g., foot checks, checking blood glucose levels, preparing nutritious meals) and transportation (e.g., getting to and from clinic visits) can be greatly hindered by impaired vision (NASEM, 2016). Additionally, vision impairment can affect the individual's ability to be compliant with medication adherence and management (e.g., reading pill bottles, self-administering insulin injections or eye drops). Therefore, individuals with diabetes who develop vision loss experience more challenges to successfully managing their condition (NASEM, 2016). Furthermore, individuals with diabetes tend to suffer from coexisting morbidities (e.g., obesity, cardiovascular disease) that can further worsen their health, and are at risk for developing several different complications including diabetic retinopathy.

Diabetic Retinopathy

Epidemiology and Risk Factors

Diabetic retinopathy is a common complication of both type 1 and type 2 diabetes. To examine the global prevalence and major risk factors of diabetic retinopathy, Yau et al. (2012) performed a pooled meta-analysis of 35 population-based studies conducted from 1980-2008 in the U.S., Asia, Australia, and Europe. Based on the findings of this analysis, the overall global prevalence of any diabetic retinopathy (defined as presence of NPDR, PDR, DME, or any combination thereof) was 34.6%, and the overall global prevalence of PDR and DME was 7.0%

and 6.8%, respectively. Pooled analysis of the studies found that the age-standardized prevalence of any diabetic retinopathy was highest among African Americans and lowest among Asians. Longer diabetes duration, higher blood pressure, higher HbA1c levels, and type 1 diabetes were associated with higher prevalence of diabetic retinopathy (Yau et al., 2012). However, studies have shown that maintaining optimal glycemic levels, blood pressure levels, and serum lipid levels can reduce the risk or slow the progression of diabetic retinopathy (Chew et al., 2014; Estacio et al., 1998; Klein, 1995; Leske et al., 2005).

At present, a national surveillance system for reporting diabetic retinopathy exists neither in the U.S. nor in other countries. The most current national estimate of diabetic retinopathy prevalence comes from the National Health and Nutrition Examination Survey (NHANES). Using data from the 2005-2008 NHANES, Zhang et al. (2010) estimated the prevalence of diabetic retinopathy and vision-threatening diabetic retinopathy (i.e., defined as the presence of severe NPDR, PDR, or DME) among people with diabetes aged 40 years and older was 28.5% and 4.4%, respectively. The prevalence among the overall U.S. population during that time period was 3.8% for diabetic retinopathy and 0.6% for vision-threatening diabetic retinopathy (e.g., severe NPDR, PDR, and DME). Significant risk factors for diabetic retinopathy that were identified included male sex, higher hemoglobin A1c (HbA1c) level, longer duration of diabetes, and higher systolic blood pressure (Zhang et al, 2010).

Another population-based study based on a regional cohort was conducted to examine the incidence of diabetic retinopathy. A longitudinal study, the Wisconsin Epidemiologic Study of Diabetic Retinopathy (WESDR) consisted of a sample of patients with diabetes who received primary care in an 11-county area in southern Wisconsin from 1979 to 1980 (Klein et al., 1998). The sample consisted of individuals with either type 1 or type 2 diabetes. Participants were assessed at baseline and followed for 4, 10, 14, and 25 years. Numerous reports regarding the incidence and progression of diabetic retinopathy and DME have been generated from the study. In a WESDR report of individuals with type 1 diabetes, the 14-year incidence of any diabetic retinopathy was 95.9% and the 14-year incidence of DME was 26.1% (Klein et al., 1998). For patients with diabetic retinopathy at baseline, 36.8% had progressed to PDR (Klein et al., 1998). Women, individuals with higher HbA1c, and individuals with higher diastolic blood pressure were at greater risk for diabetic retinopathy progression. Individuals with higher HbA1c, with higher systolic and diastolic blood pressures, and with hypertension and proteinuria were at higher risk for developing PDR. (Klein et al., 1998). Factors associated with increased incidence of DME included severe baseline retinopathy, higher HbA1c at baseline, and presence of gross proteinuria at baseline. In subgroup analysis, the study assessed the relationship between the age and duration of diabetes at baseline and the 14-year progression of any diabetic retinopathy, 14-year progression to PDR, and 14-year incidence of DME. A significant inverse relationship was found between age at baseline examination and progression of any diabetic retinopathy with the highest rate found in individuals ≤19 years of age and the lowest rate found in individuals ≥35 years of age. The 14-year progression to PDR was found to be significantly associated with the duration of diabetes at baseline. Persons with ≥10 years of diabetes at baseline were 1.97 times more likely to develop PDR and DME over the 14 years follow-up compared to persons with <10 years of diabetes at baseline (Klein et al, 1998). The study did not include subgroup analysis by race and ethnicity.

Disease Burden

Diabetic retinopathy is recognized as a major cause of blindness and visual impairment worldwide. To estimate the number of people affected by blindness and visual impairment, Leasher et al. (2016) conducted a meta-analysis of global population-based studies that included data from 1990-2010. Some of the areas represented in the study included Pacific Asia, Australasia, Caribbean, Central, Eastern, and Western Europe, Andean, Central, Southern, and Tropical Latin America, Oceania, North American, and Sub-Saharan Africa. Analyses revealed that diabetic retinopathy accounted for 2.6% (833,690) of blindness and 1.9% (3.7 million) of visual impairment (Leasher et al., 2016). Diabetic retinopathy-related blindness increased by 27% and diabetic retinopathy-related visual impairment increased by 64% from 1990 to 2010. Further analysis revealed that of all global blindness causes, the percentage caused by diabetic retinopathy increased from 2.1 in 1990 to 2.6% in 2010 (Leasher et al., 2016).

Although diabetic retinopathy is primarily associated with causing visual impairment and blindness, it can also be an indicator for other systemic vascular complications. Findings from the Framingham Heart and Eye Study indicated individuals with diabetes who had microvascular disease (e.g., diabetic retinopathy) were more likely to have macrovascular disease (e.g., cardiovascular disease) (Hiller et al., 1988). Both NPDR and PDR have been linked with conditions such as stroke, coronary heart disease, heart failure and nephropathy (Wong et al., 2001). Furthermore, diabetic retinopathy has been associated with an increased risk of mortality, particularly in individuals with cardiovascular risk factors (Cheung & Wong, 2008). In a pooled analysis of 17 prospective, observational studies, results revealed that in patients with type 2 diabetes, the odds for all-cause mortality and/or cardiovascular events were 2.34 times as high for patients with diabetic retinopathy compared to patients without diabetic retinopathy. Similarly, for patients with type 1 diabetes, the odds for all-cause mortality and/or cardiovascular events were 4.1 times as high for patients with diabetic retinopathy compared to patients without diabetic retinopathy (Kramer et al., 2011).

Screening

As diabetic retinopathy can progress with few or no visual symptoms, it is important that individuals with diabetes receive adequate eye screening for early detection and subsequent intervention. The aim of early detection through screening is to discover and treat conditions which have already produced pathological change, but which have not reached a stage where medical aid has been sought spontaneously (Wilson et al., 1968). Diabetic retinopathy is optimal for screening because it is asymptomatic until advanced, highly prevalent, relatively easy to detect, and confined to a well-defined population (people with diabetes) (Wong et al., 2016). Furthermore, screening methods for diabetic retinopathy are relatively inexpensive, non-invasive, and there are clear treatment modalities for treating both early stage diabetic retinopathy and DME that can prevent further progression and subsequent harm (ADA, 2019; Wong et al., 2016). Research has shown that screening is effective in detecting diabetic retinopathy and preventing blindness (ADA, 2019; Ding & Wong, 2012; Fong et al., 2001; Singer et al., 1992; Solomon et al., 2017).

For adults with type 1 or type 2 diabetes, the ADA makes the following screening recommendations:

- Adults with type 1 diabetes should have an initial dilated and comprehensive eye examination by an ophthalmologist or optometrist within 5 years after the onset of diabetes.
- Patients with type 2 diabetes should have an initial dilated and comprehensive eye examination by an ophthalmologist or optometrist at the time of the diabetes diagnosis.

- If there is no evidence of retinopathy for one or more annual eye exam and glycemia is well controlled, then exams every 1–2 years may be considered. If any level of diabetic retinopathy is present, subsequent dilated retinal examinations should be repeated at least annually by an ophthalmologist or optometrist. If retinopathy is progressing or sight-threatening, then examinations will be required more frequently
- Telemedicine programs that use validated retinal photography with remote reading by an ophthalmologist or optometrist and timely referral for a comprehensive eye examination when indicated can be an appropriate screening strategy for diabetic retinopathy (ADA, 2019, p. 129).

Treatment

The purpose of diabetic retinopathy screening is to identify individuals who may be at increased risk for developing a visual impairment or vision loss. Timely identification of signs and symptoms of diabetic retinopathy reduces an individual's chances of worsening the condition through appropriate treatment. Current treatments for diabetic retinopathy including laser photocoagulation and anti-vascular endothelial growth factor (anti-VEGF) injections can reduce the risk of vision loss through disease regression. Panretinal photocoagulation for PDR involves placing laser burns over the entire retina to promote regression and arrest progression of retinal neovascularization (Cheung et al., 2010). In a clinical trial of over 1,758 patients with PDR, the Diabetic Retinopathy Study (DRS) found panretinal photocoagulation reduced the risk of severe visual loss by 50% over 5 years ("Photocoagulation treatment of proliferative diabetic retinopathy. Clinical application of Diabetic Retinopathy Study [DRS] findings, DRS Report Number 8. The Diabetic Retinopathy Study Research Group," 1981). Similarly, in a clinical trial of 3,711 patients with less severe diabetic retinopathy, the Early Treatment Diabetic Retinopathy Study (ETDRS) found early administration of the therapy reduced the risk of progression to PDR by 50% ("Focal photocoagulation treatment of diabetic macular edema. Relationship of treatment effect to fluorescein angiographic and other retinal characteristics at baseline: ETDRS report no. 19. Early Treatment Diabetic Retinopathy Study Research Group," 1995). For treatment of DME, photocoagulation is used to target individual leaky blood vessels near the macula. The ETDRS found a 50% reduction in the risk of visual loss from clinically significant DME after macular laser treatment ("Focal photocoagulation treatment of diabetic macular edema. Relationship of treatment effect to fluorescein angiographic and other retinal characteristics at baseline: ETDRS report no. 19. Early Treatment Diabetic Retinopathy Study Research Group," 1995).

Although laser photocoagulation is considered the standard ocular treatment for diabetic retinopathy and DME, ocular injection of anti-VEGF has been introduced as an alternative treatment method. A randomized clinical trial of 305 adults with PDR demonstrated intravitreal injections of an anti-VEGF agent, specifically ranibizumab, resulted in visual acuity outcomes that were not worse than outcomes observed in patients treated with panretinal photocoagulation at 2 years of follow up (Writing Committee for the Diabetic Retinopathy Clinical Research et al., 2015). Additional outcomes observed for the ranibizumab treatment group were less peripheral visual field loss, fewer vitrectomy surgeries for secondary complications from their proliferative disease, and a lower risk of developing DME (ADA, 2019; Writing Committee for the Diabetic Retinopathy Clinical Research et al., 2015).

In cases where NPDR, PDR or DME is detected through screening, patients should be referred to an ophthalmologist who is knowledgeable and experienced in the management of diabetic retinopathy (ADA, 2019). The ADA provides the following guidelines for treatment:

- Promptly refer patients with any level of macular edema, severe nonproliferative diabetic retinopathy (a precursor of proliferative diabetic retinopathy), or any proliferative diabetic retinopathy to an ophthalmologist who is knowledgeable and experienced in the management of diabetic retinopathy.
- The traditional standard treatment, panretinal laser photocoagulation therapy, is indicated to reduce the risk of vision loss in patients with high-risk proliferative diabetic retinopathy and, in some cases, severe non-proliferative diabetic retinopathy.
- Intravitreous injections of anti–vascular endothelial growth factor ranibizumab are not inferior to traditional panretinal laser photocoagulation and are also indicated to reduce the risk of vision loss in patients with proliferative diabetic retinopathy.
- Intravitreous injections of anti–vascular endothelial growth factor is indicated for central-involved diabetic macular edema, which occurs beneath the foveal center and may threaten reading vision. (ADA, 2019, p 129)

Costs

Studies have shown that diabetics with retinopathy have significantly higher medical costs than those without retinopathy (Schmier et al., 2009; Zhang et al., 2017). A recent study performed in Singapore of adults (21-90 years) with type 2 diabetes found that the median of total costs in individuals with diabetic retinopathy was significantly higher than that in individuals without diabetic retinopathy. Further, costs increased with increasing severity of diabetic retinopathy with cost ratios of 1.1, 1.8, 2.0, and 2.3 for mild, moderate, severe NPDR, and PDR, respectively, relative to non-diabetic retinopathy respectively (Zhang et al., 2017). A U.S. study that analyzed Medicare claims data of diabetic beneficiaries with NPDR or PDR to diabetic beneficiaries with no evidence of diabetic retinopathy reported similar findings (Schmier et al., 2009). Their study of diabetic adults (≥65 years) found that the annual average costs for both all care and ophthalmic care were significantly higher for beneficiaries with NPDR or PDR compared to beneficiaries without diabetic retinopathy (Schmier et al., 2009). They also found that average payments for all care and for ophthalmic care were substantially higher for PDR cases compared to NPDR cases (Schmier et al., 2009). Early detection and treatment of diabetic retinopathy has the potential to significantly reduce diabetes-related medical costs.

Many studies have used computer simulation modeling to evaluate the cost-effectiveness of screening and treatment for diabetic retinopathy (Crijns et al., 1999; Javitt et al., 1994; Javitt et al., 1996; Jones et al., 2010; Polak et al., 2003). Using data from U.S. population-based epidemiological studies and clinical trials, along with data on federal budgetary costs of blindness, Javitt et al. (1994) estimated the current and potential federal savings resulting from the screening and treatment of and treatment of retinopathy in patients with type II diabetes. Screening and treatment of diabetic retinopathy resulted in projected savings of $247.9 million to the federal budget and 53,986 person-years of sight (Javitt et al, 1994). This study projected that enrolling each additional person with type II diabetes into currently recommended ophthalmological care would result in an average net savings of $975/person (Javitt et al, 1994).

Additional studies have also examined the cost-effectiveness of diabetic retinopathy screening and treatment in terms of prevented blindness or years of avoided sight loss. A study based in the Netherlands simulated the progression of diabetic retinopathy in a population of

20,000 patients. The study found that in younger onset (<25 years) patients, screening reduced the prevalence of blindness by 52%; however, little benefit was seen from screening in terms of reduction in blindness later onset (>75 years) patients (Crijns et al., 1999). In a similar study that modeled the cost-effectiveness of ophthalmological care (screening and treatment) in relation to the progression of diabetic retinopathy, different scenarios of ophthalmological screening were used to determine their cost-effectiveness in preventing blindness due to diabetic retinopathy (Polak et al., 2003). Also performed in the Netherlands, the study found that screening was most cost-effective in patients with earlier onset of diabetes. For patients with age of onset of 15 years, the simulation model found that those who received screening frequently (i.e., 1 year if no diabetic retinopathy present, twice a year if any diabetic retinopathy present, and 4 times a year if ME or PDR present) had a lifetime sight gain of 532 years/1000 patients when compared to those who did not receive screening. This rate diminished with increasing age in those with an onset of 35 years, 50 years, and 65 years and their lifetime sight gain was 125 years/1000 patients, 63 years/1000 patients, and 16 years/1000 patients, respectively (Polak et al., 2003).

Factors Influencing Diabetic Retinopathy Screening

As with any health behavior, there are many factors that can influence whether an individual obtains diabetic retinopathy screening. The literature reports mixed findings on race and ethnicity as a contributing factor to diabetic retinopathy screening. In adjusted analyses of 2002-2013 MEPS data, Tran, et al. (2017) found that the non-Hispanic whites were more likely than Asians to report having an eye examination but did not find a significant difference in eye examination rates between non-Hispanic whites and other minority groups (i.e., Hispanics and non-Hispanic blacks). Contrastingly, Chen et al. (2014) found in adjusted analyses that both non-Hispanic blacks and Hispanics were more likely than non-Hispanic whites to report having an eye examination. Shi et al. (2014) reported the opposite in that non-Hispanic whites were more likely to have dilated eye examinations compared to minority populations (i.e., all other non-Hispanic whites including blacks, Hispanics, American Indian/Alaska native, Asian, native Hawaiian/Pacific islander, or multiple races).

In addition to race and ethnicity, other sociodemographic factors such as age, education, sex, marital status, income and insurance status have also been associated with diabetic retinopathy screening. Population-based studies of 2002-2009 MEPS data (Shi et al., 2014), 2001-2010 BRFSS data (Chen et al., 2014), and 2014-2015 MEPS data (Monnette et al., 2019) found that older individuals (aged ≥45 years) were more likely to report receiving an eye examination compared to younger individuals (aged<45 years). Education level was also shown to influence screening as the likelihood of obtaining an eye examination increased with increasing levels of education. Individuals with no high school diploma were less likely to obtain an eye examination compared to individuals with a high school diploma (Chen et al, 2014; Monnette et al., 2019; Shi et al. 2014; Tran et al., 2017), bachelor's degree (Monnette et al., 2019; Tran et al., 2017), or professional degree (Tran et al., 2017). Women and married/partnered individuals were also more likely to report receiving an eye examination (Chen et al., 2014; Monnette et al., 2019; Tran et al., 2017). Lastly, additional socioeconomic factors found to be associated with eye examination were income ≥400 of the federal poverty level (FPL) (Tran et al., 2017) or income >$50,000 (Chen et al, 2014) and having either private or public insurance (Chen et al, 2014; Monnette et al., 2019; Shi et al. 2014; Tran et al., 2017). Other health and health care-related factors found to be positively associated with eye examinations were having a usual provider (Chen et al., 2014; Tran et al., 2017) and insulin use (Chen et al., 2014). Duration of diabetes was shown to be positively associated with diabetic retinopathy prevalence and thus, might influence eye examination utilization (ADA, 2019; Solomon et al., 2017; Zhao et al., 2014).

In addition to factors that may increase the likelihood that an individual obtains diabetic retinopathy screening, several barriers to screening have also been identified. While there are many approaches to categorizing barriers, in a review of the literature, Nsiah-Kumi, Ortmeier, and Brown (2009) identified patient-, provider-, and health care system-related barriers to screening decisions. A common patient-level theme identified in the literature was a lack of knowledge and understanding of diabetic retinopathy, diabetic retinopathy screening, and diabetic retinopathy treatment (Hartnett, Key, Loyacano, Horswell, & Desalvo, 2005; Nsiah-Kumi et al., 2009; Schoenfeld, Greene, Wu, & Leske, 2001; Walker et al., 1997). Studies found that patients did not understand the rationale for obtaining annual eye exams (Hartnett et al. 2005) and did not believe they were necessary (Roy, 2004; Schoenfeld et al., 2001). Additional barriers identified were that patients had never been told by their physician to have an annual eye exam (Roy, 2004; Walker et al., 1997) or patients had been unaware of or lacked eye-related symptoms (Hartnett et al. 2005; Roy, 2004; Walker et al., 1997). Affordability and being too busy to schedule an appointment were also identified as barriers to obtaining an eye examination (Hartnett et al., 2005; Moss et al., 1995; Roy, 2004; Walker et al., 1997). For non-English-speaking Hispanics, for example, language barriers, and access to specialty care have been identified as obstacles to obtaining recommended screening (Kirk et al., 2008; Nsiah-Kumi et al., 2009).

Along with patient factors, provider-related factors have also been identified as barriers to diabetic retinopathy screening. These include lack of awareness about screening guidelines and lack of skills or equipment to perform eye exams (Walker et al., 1997). Contributors to poor screening completion rates include inadequate patient education (Moss et al., 1995; Walker et al., 1997), poor patient-physician communication (Chin et al., 2001; Hartnett et al., 2005), and insufficient appointment time with providers (Chin et al., 2001; Nsiah-Kumi et al., 2009). In a population-based study of patients and their physicians, Mukamel et al. (1999) explored various barriers to compliance with diabetic retinopathy screening guidelines. A significant factor identified that influenced the probability of screening was the average number of primary care physician visits each patient had. For patients who visited their primary care physician more often, the probability of screening was significantly higher, suggesting that more contact with the primary care physician may lead to more time for interaction and education of the patient (Mukamel et al., 1999; Nsiah-Kumi et al., 2009).

System-level factors include lack of insurance coverage, long wait times for appointments, and difficulties in scheduling appointments (Hartnett et al., 2005; Nsiah-Kumi et al., 2009; "Photocoagulation treatment of proliferative diabetic retinopathy. Clinical application of Diabetic Retinopathy Study (DRS) findings, DRS Report Number 8. The Diabetic Retinopathy Study Research Group," 1981). In a study of a Latino population, those with lack of health care coverage were twice as likely to not have visited the doctor in the previous year nor have had an eye exam (Varma et al., 2004). Additionally, understaffing and high turnover of specialized physicians such as optometrists and ophthalmologists contribute to poor screening completion (Silver et al., 2006).

In Shi's et al. study (2014), health insurance coverage was identified as a strong predictor for receiving an eye examination. However, not all types of health insurance coverage are created equal in that some plans contain benefits that others do not. Lack of certain benefits, such as coverage for specialists including ophthalmologists and optometrists, who often perform eye examinations, can directly affect an individual's self-monitoring behavior of obtaining preventive screenings. In Shi et al. study (2014), the researchers observed insurance coverage decreased over the years with minorities being affected to a larger degree than non-Hispanic whites. However, even within the insured population, minorities still obtained eye examinations to a lesser extent than non-Hispanic whites. Hence, it is possible that insurance coverage alone may not fully address the racial and ethnic disparity seen in eye examination rates. The authors surmise that in addition to health insurance coverage, other factors could contribute to the disparities seen in diabetic retinopathy screening in this study. For example, patient's attitudes toward screening or referral by a health care provider are factors that can affect the uptake of diabetic retinopathy screening services (Van Eijk et al., 2012). Additionally, the geographical distribution of ophthalmologists and optometrists may also affect diabetic retinopathy screening as in the areas with fewer ophthalmologists and optometrists, fewer dilated eye examinations may be performed (Chou et al., 2012; Gable et al., 2000).

Further supporting this idea that other factors can contribute to screening, a cross-sectional study of insured veterans at 21 Veteran Affairs' facilities reported that a significantly lower percentage of black patients had received a dilated eye examination in the past year compared to white patients (Heisler et al., 2003). Even after adjusting for several covariables (patients' age, education, income, insulin use, diabetes self-management, duration, severity, comorbidities, and health services utilization), the racial differences in receipt of eye examinations persisted (Heisler et al., 2003). Considering that all participants in the study were insured, these findings highlight the need to examine other health care system factors when examining racial and ethnic differences in rates of eye exams. In this study, nearly all the racial disparity in receipt of eye examination was explained by blacks disproportionately receiving care at facilities with poorer performance on that quality measure suggesting that improving the rate of screening at low-performing facilities may improve racial disparities in eye care (Heisler et al., 2003).

Andersen Healthcare Utilization Model

The multitude of factors that have been associated with screening have been categorized in different ways. For example, prior studies have characterized them as patient-level, provider-level or system-level factors. One approach to characterizing influencing factors is through the Andersen Healthcare Utilization model. The model was created by Ronald Andersen in 1950 and has been used in health behavioral studies to predict and explain use of health services. The model suggests that health service utilization is determined by the individual's propensity to use or not use services (predisposing factors), facilitators or impediments to use of service (enabling factors) and needs or perceived need for care (need factors) (Andersen et al., 2013; Lee et al., 2018). The model has evolved over time to include contextual determinants of health services utilization which can include organization and provider-related factors as well as community characteristics (Andersen et al., 2014).

The variables that were considered to operationalize the Andersen Healthcare Utilization model are depicted in Figure 2.1. Consistent with the literature review provided earlier in this chapter, predisposing factors explored in this study will include age, sex, marital status, and education. Enabling factors will include economic status as a percentage of the federal poverty level, whether individual has a usual source of care, and insurance status. Need factors will include duration of diabetes and insulin use. As depicted in Figure 2.1, the predisposing variables impact enabling variables, which impact need variables and all three constructs influence the likelihood of healthcare utilization.

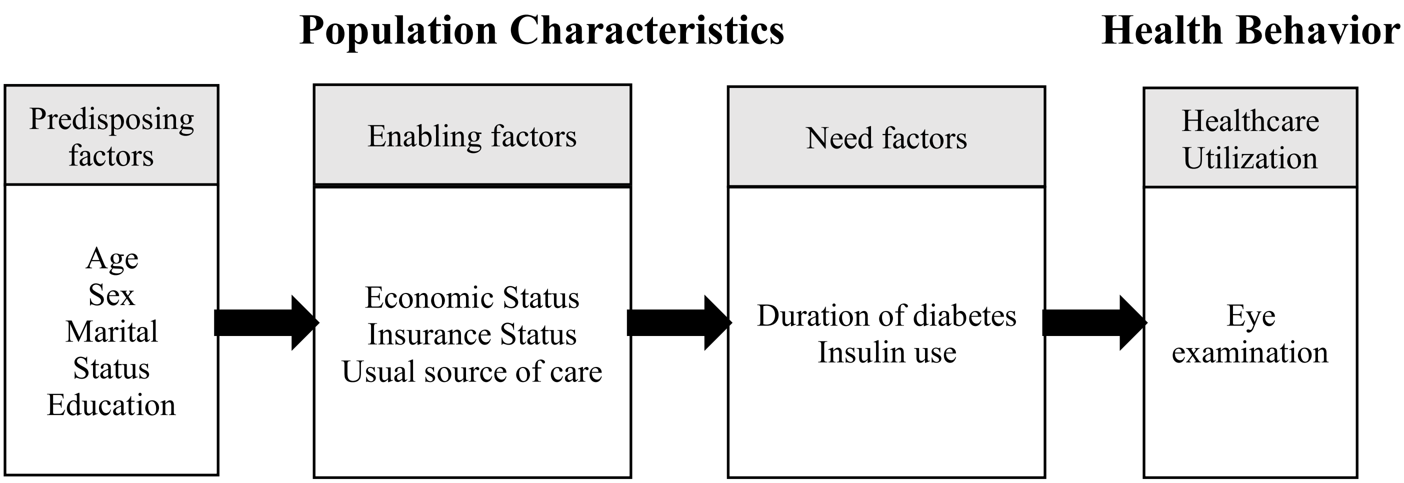

Figure 2.1. Conceptual Framework: Andersen's Healthcare Utilization Model

Through its various provisions that aimed to expand insurance coverage, the ACA was forecasted to increase rates of health insurance coverage and reduce financial barriers to service use among millions of at need Americans. Since racial and ethnic minorities are more likely to be uninsured and lack access to care including preventive screenings (Agency for Healthcare Research and Quality [AHRQ], 2011; 2017), ACA implementation should have consequently lessened some of these disparities. Therefore, this study will examine the effects of the ACA while controlling for predisposing, enabling, and need factors.

The Role of Health Insurance in Addressing Racial and Ethnic Disparities

Health insurance is an important resource for people because it can increase their ability to obtain necessary medical care and protect them against financial burdens that come with unexpected medical events. This is particularly true for racial and ethnic minorities who historically have experienced poorer overall health status compared to whites (Heckler, 1985). As health insurance is a fundamental component in obtaining positive health outcomes, particularly in minority populations, much research has been done to understand the impact health insurance coverage may have in reducing disparities in health services. In a review of the literature, Lillie-Blanton and Hoffman (2005) identified articles that answered the question: How much of racial and ethnic disparities in access to care can be explained by differences in health insurance status? The review included original research studies that 1) compared whites to a specific racial and ethnic group (blacks or Hispanics); 2) measured the effects of racial and ethnic differences in social, economic, or health system factors that may contribute to disparities in access to health care; and (3) quantified the contribution of racial and ethnic differences in health insurance on disparities in access to care (Lillie-Blanton & Hoffman, 2005). Four studies were identified that applied regression-based methods so that multiple factors could be isolated to determine each factor's contribution to racial and ethnic disparities in access to care (Lillie-Blanton & Hoffman, 2005). The studies used several measures of access; however, the measure of access that was common across all four studies was whether the individual had a usual source of care. Therefore, the researchers used this as their measure of health care access (Lillie-Blanton & Hoffman, 2005).

Overall, the studies found both Hispanics and blacks were significantly less likely than whites to have a usual source of care. However, a larger access gap was seen between Hispanics and whites than between blacks and whites. Across all four studies, the access gap between Hispanics and whites ranged between 15 to 16 percentage points, and the access gap between blacks and whites ranged between 4.4 to 8.4 percentage points (Hargraves & Hadley, 2003; Waidmann & Rajan, 2000; Weinick et al., 2000; Zuvekas & Taliaferro, 2003). In examining the contribution of insurance coverage in explaining the access gap, health insurance consistently explained a significant share (23-33%) of the Hispanic-white access difference and was the single largest observable factor in all but one study where both health insurance and income contributed the same share (23%) (Weinick et al., 2000). For three of the four studies, health insurance explained 24 to 42% of the black-white access difference. In the Weinick et al. (2000) study, insurance only accounted for 5%, whereas income accounted for 41% of the access gap. The only other factor that contributed a sizable share to the black-white access gap was family structure (26%) (Waidmann & Rajan, 2000). In summary, these studies demonstrated health insurance accounted for a sizable share of racial and ethnic disparities in access to a usual source of care (Lillie-Blanton & Hoffman, 2005).

Of the eight comparisons in this review, health insurance explained a statistically significant share of the access gap in all four comparisons between Hispanics and whites and in three of the four comparisons between African Americans and whites (Lillie-Blanton & Hoffman, 2005). The one study that deviated from these otherwise consistent findings is the Weinick et al. (2000) study which differed in the way it structured its statistical analyses. In that study, the regression analysis included an interaction term for racial and ethnic characteristics and insurance status to separate the effect of racial and ethnic differences in health insurance on access to care (Lillie-Blanton & Hoffman, 2005). In order to examine how differences in insurance status and income might play a role in explaining racial and ethnic disparities, the researchers estimated linear probability models with an interaction term between 1) race and ethnicity and health insurance and 2) race and ethnicity and family income. They then used the regression estimates to simulate how much of the disparities between Hispanic and whites and between blacks and whites would change if Hispanics and blacks had health insurance coverage and income that was equivalent to that of whites (Weinick et al., 2000). The researchers found that changing the insurance coverage of blacks to be equivalent to that of whites had no statistically significant impact on the black-white disparity for usual source of care. Contrastingly, when changing the insurance coverage of Hispanics to match that of white, a 23%

reduction was seen in the Hispanic-white disparity for usual source of care. Changing the income of blacks and Hispanics to be equivalent to that of whites resulted in a 41% reduction in the black-white disparity and 21% reduction and the Hispanic-white disparity in usual source of care (Weinick et al., 2000).

The remaining three studies utilized a regression decomposition method that allowed them to decompose the percentages of the total disparity that is associated with differences in the independent variables of interest. For instance, if the researcher were interested in determining how much of the total disparity was attributed to racial and ethnic differences in income, the researcher could simulate the outcome among one racial and ethnic group if that group had the income distribution of another racial and ethnic group while holding all other characteristics the same.

The Affordable Care Act

Provisions and Mandates

The Patient Protection and Affordable Care Act, often shortened to the Affordable Care Act (ACA), was signed into law by President Barack Obama on March 23, 2010. The ACA attempted to achieve comprehensive health reform by improving health care access, quality, and cost control (McDonough, 2014; Sealy-Jefferson et al., 2015). The ACA includes numerous components intended to reduce health disparities, improve the quality of care, and address health insurance reform among racially and ethnically diverse populations (Andrulis et al., 2010).

Several provisions of the ACA can be expected to have a positive impact on racial and ethnic minorities. Federal or state government-sponsored health insurance marketplace exchanges were established to provide private health insurance for individuals who are not otherwise eligible for Medicaid based on income, age, parenting status or other eligibility requirements and who do not have access to employer-sponsored health insurance (McDonough, 2014). Premium tax credits are available to individuals with incomes between 100-400% of the FPL who purchase health insurance through the marketplace exchange (Frean et al., 2017). Additionally, cost-sharing subsidies are available to eligible individuals to help reduce the portion of a claim that the insured will have to pay (KFF, 2012). The ACA health insurance marketplace exchanges commenced operation in every state on October 1, 2013, and by April 2014, more than 8 million Americans purchased coverage through the ACA health insurance marketplace (ASPE, 2014).

Another concrete action expected to affect racial and ethnically diverse people include employer-based health insurance reforms. In 2005, 71 percent of working-age whites had health insurance through their workplace, whereas only one-third of working-age Hispanics and half of working-age African Americans had employer-sponsored coverage (Doty & Holmgren, 2006). With ACA implementation, employers with ≥200 employees are mandated to automatically enroll employees into their health insurance plans, and employers with ≥50 employees must offer coverage to employees or pay a penalty for full-time employees that receive a tax credit for purchasing insurance through the exchanges (Andrulis et al., 2010; French et al., 2016; KFF, 2012). Small employers with fewer than 25 full-time employees with average annual wages of less than $50,000 qualify for employer tax credits (H.R. 3590, 2010). Given that over 90% of minority-owned firms are small employers (≤25 employees), and diverse populations are more likely to be employed by small firms, the employer mandate has the potential to expand coverage for a sizeable amount of racially and ethnically diverse people (Lowrey, 2007).

Low-income racially and ethnically diverse populations are expected to benefit the most from the expansion of Medicaid. Medicaid is a federal and state program that provides health insurance for many, though not all, low-income Americans (McDonough, 2014). The types of services offered vary by state; however, states are required by federal law to provide certain mandatory benefits. Some of these mandatory benefits include early and periodic health screening, diagnostic, and treatment services, inpatient and outpatient hospital services, physician services, laboratory and X-ray services, family planning services, transportation to medical care, nursing facility services, Certified Pediatric and Family Nurse Practitioner services, and home health services Optional benefits that states may provide include prescription drugs, prosthetics, eye glasses, physical therapy, occupational therapy, podiatry, optometry, chiropractic, and dental services (Centers for Medicare & Medicaid Services, n.d.).

Prior to ACA implementation, Medicaid income eligibility limits varied by state with some states (i.e., Alabama and Texas) setting their income eligibility for Medicaid well below 20% of FPL. As implemented in January 2014, ACA Medicaid expansion extended coverage to individuals living at or below 138% of the FPL (Sealy-Jefferson, 2015). However, because of the Supreme Court's ruling in the National Federation of Independent Business v. Sebelius case, states have the choice to opt out of implementation, so expansion is not consistent throughout the U.S. (Rosenbaum & Westmoreland, 2012). As of September 2019, 36 states and the District of Columbia have adopted Medicaid expansion, whereas 14 states have not (KFF, 2019b). For states that did not adopt Medicaid expansion, individuals whose incomes are above the Medicaid eligibility boundary for that state but below the lower limit to receive premium tax credits for marketplace insurance likely fall into the "coverage gap" and can remain uninsured (McDonough, 2014).

Along with expanding both public and private insurance coverages, the ACA also imposed new insurance regulations. For plan years through 2018, the individual mandate requires most Americans without employer-sponsored health insurance to obtain health insurance or pay a penalty; however, Congress reduced the individual mandate penalty to $0 effective in 2019 (Kamal et al., 2018). Young adults can remain under their parents' health insurance until the age of 26 (dependent coverage provision). Insurance companies can no longer deny coverage to individuals based on health status or pre-existing conditions and can no longer charge more based on gender or health status (KFF, 2012). Insurers must provide comprehensive health plans that cover essential health benefits which include items and services in the following ten benefit categories: 1) ambulatory patient services; 2) emergency services; 3) hospitalization; 4) maternity and newborn care; 5) mental health services and substance use disorder services; 6) prescription drugs; 7) rehabilitative services and devices; 8) laboratory services; 9) preventive services (i.e., screenings), wellness services, and chronic disease treatment; and 10) pediatric services (Centers for Medicare & Medicaid Services, n.d.). Lastly, the ACA prohibits insurers from imposing lifetime limits on coverage and prohibits them from rescinding coverage, except in cases of fraud (KFF, 2012). Through its various provisions, the ACA intends to make insurance options available to individuals who may not have been able to afford insurance or had access to employer-sponsored insurance prior to its implementation.

The ACA and Insurance Coverage by Race and Ethnicity

Analysis of data from the 2013 to 2016 American Community Survey (ACS) found that since ACA implementation, the proportion of uninsured Americans aged 0 to 64 fell from 17.0 percent to 10.0 percent, meaning 18.5 million more Americans gained health insurance coverage (Skopec et al., 2018). Of this 18.5 million people, 10.9 million people had Medicaid coverage and 6.3 million people had private non-group coverage (Skopec et al., 2018). Although both expansion and non-expansion states saw significant reductions in uninsured rates, states that expanded Medicaid saw a larger reduction in uninsured rates under the ACA. Between 2013 to 2016, the uninsured rate fell by more than 50 percent in Medicaid expansion states with an additional 12.6 million people gaining coverage of which 9.7 million gained Medicaid coverage (Skopec, et al., 2018). In non-expansions states, the uninsured rate had a 31 percent decline, largely due to gains in private non-group coverage and employer-sponsored insurance (Skopec, et al., 2018). In 2016, uninsured rates for all racial and ethnic groups significantly fell and racial and ethnic gaps in uninsured rates narrowed. The uninsured rate fell by 8.2, 10.8, and 8.4 percentage points for non-Hispanic blacks, Hispanics, and other or multiple races, respectively, compared to 5.7 percentage points for non-Hispanic whites (Skopec et al., 2018).

In population-based studies of adults aged 18-64 years, Buchmueller et al. (2016), Chen et al. (2016), and McMorrow et al. (2015) found the percentage of uninsured adults significantly decreased for all racial and ethnic groups after implementation of the most significant pieces of the ACA such as young adult coverage (e.g., adults may remain on a parent’s insurance until the age of 26 year), marketplace exchanges, and Medicaid expansion; however, there was a larger decrease for blacks and Hispanics compared to whites (Buchmueller et al., 2016; Chen et al., 2016). Additionally, there was a significant reduction in both the white-black and white-Hispanic coverage gaps after the 2014 ACA policy implementation (Buchmueller et al., 2016; McMorrow et al., 2015).

McMorrow et al. (2015) utilized data from the National Health Interview Survey (NHIS) to examine changes in insurance coverage disparity gap among blacks, whites, and Hispanics through December 2014. Measuring absolute disparity (e.g., the difference between percentage of uninsured white and either the percentage of uninsured blacks or percentage of uninsured Hispanics) and relative disparity (e.g., the ratio of the percentage of uninsured blacks or

Hispanics to the percentage of uninsured whites), the study found a significant reduction in both absolute and relative disparity for black adults and a significant reduction in absolute disparity for Hispanics (McMorrow et al., 2015). However, when stratifying by state expansion status, Hispanics experienced a significant increase in relative disparity in expansion states, whereas blacks experienced a significant decline in relative disparity in non-expansion states. The authors surmise that the decline in relative disparity for blacks in non-expansion states may be due to strong Marketplace enrollment and increased participation among those previously eligible for Medicaid and that the incline in relative disparity for Hispanics in expansion states likely reflects immigrants' restricted access to Medicaid and subsidies for Marketplace coverage (McMorrow et al, 2015). In a complementary study, Buchmueller et al. (2016) investigated the changes in the source of coverage using data from the 2008-2014 ACS. Findings revealed both private and public insurance coverages increased more for blacks and Hispanics than for Whites between 2013 and 2014, and coverage gains were greater in states that expanded Medicaid (Buchmueller et al., 2016).

Additional studies of the ACA's effects of the Medicaid expansion on racial and ethnic disparities in insurance coverage found mixed empirical results (Lee & Porell, 2018; Yue et al., 2018). In a quasi-experimental study examining the low-income (<138% FPL) adult population using 2013-2015 BRFSS data, Medicaid expansion was associated with a significant increase in the coverage gap between whites and Hispanics (Yue et al., 2018). Additionally, in a quasi-experimental study of 2011-2016 BRFSS data, Lee and Porell (2018) also saw a widening of the coverage gap between whites and Hispanics in expansion versus non-expansion states; however, this result was not statistically significant. Neither study saw a significant change in the coverage gap between whites and blacks (Lee & Porell, 2018; Yue et al., 2018).

Both studies have also examined measures of access (e.g., having a usual source of care, having a personal doctor and being unable to see a doctor due to costs). Yue et al. (2018) found that Medicaid expansion was associated with an increase in having a personal doctor and a decrease in being unable to see a doctor due to costs for both non-Hispanic whites and non-Hispanic blacks; however, Medicaid expansion was not associated with any improvement in access outcomes for Hispanics. In fact, for the measure of having a personal doctor, researchers found that the disparity gap between non-Hispanic whites and Hispanics widened in both expansion and non-expansion states after ACA implementation. Additionally, although not statistically significant, an increase was seen in the white-Hispanic disparity for the probability of being unable to see a doctor due to costs, while a reduction was seen in the black-white disparity for the same measure (Yue et al., 2018). Similarly, Lee and Porell (2018) did not find any statistically significant evidence that Medicaid expansion reduced racial and ethnic disparities in access to care.

The ACA and Diabetic Retinopathy Screening

Although there is a considerable amount of literature that has examined the impact of the ACA on various health services and health outcomes, few studies have focused on ACA and racial and ethnic disparities regarding diabetic retinopathy screening. Shi et al. (2016) aimed to examine potential changes in eye examination rates across different racial and ethnic groups in adults (aged 18-64 years) with diabetes following ACA implementation. Using data from the 2011 MEPS, the researchers simulated respondent samples for years 2014-2017. Results revealed that eye examination rates were forecasted to increase for minorities; however, some racial and ethnic disparities in eye examinations would continue to persist (Shi et al., 2016). The data simulations used in the study relied on assumptions that population characteristics, diabetes prevalence, and other social cultural factors in the predicted years would be the same as in 2011 (Shi et al., 2016). Furthermore, the study did not examine the ACA Medicaid expansion's role in reducing racial and ethnic disparities.

In a similar study examining data from MEPS, Monnette, et al. (2019) examined changes in eye examination rates amongst individuals with diabetes from 2014 to 2015. The study revealed that eye examination rates significantly increased for both minorities (i.e., respondents not self-identified as "non-Hispanic white") and non-Hispanic whites but increased by a greater amount for minorities. Also, the racial and ethnic disparity between minorities and non-Hispanic whites was reduced from 2014 to 2015. Although the racial and ethnic disparity between minorities and non-Hispanic whites was significant in 2014, adjusted models revealed that it was no longer significant in 2015. Among this study's limitations was that it only focused on the first two years after the ACA implementation. Like Shi's et al. (2016) study, it did not examine the effects of the ACA Medicaid expansion on racial and ethnic disparities in eye examination rates among the U.S. adult diabetic population.

The present study intends to extend the research done by Shi et al. (2016) and Monnette et al. (2019) by 1) examining three full years of data post-ACA implementation; 2) calculating both absolute and relative disparities for individual racial and ethnic groups and examining how they have changed over time; and 3) using difference-in-difference analyses to examine the impact of the ACA Medicaid expansion on racial and ethnic disparities in eye examination rates among the U.S. diabetes population. At the time of this writing, this study is the first to use three full years of post-ACA data to estimate the impact of the ACA on racial and ethnic disparities in eye examination rates in U.S. adults with diabetes and is the first to focus on the effects of the ACA Medicaid expansion.

CHAPTER 3-METHODOLOGY

This chapter details the research design and methodology used in the study. The chapter is divided into sections that include an overview of the research design, data source, study population, measures, and statistical analyses.

Research Design

A trend analysis was used to examine changes in eye examination rates over time while adjusting for predisposing, enabling, and need factors. Effects of Medicaid expansion on eye screening rates were examined using a quasi-experimental research design employing a difference-in-difference (DiD) analysis, which is used to study causal relationships in public health settings where randomized controlled trials are infeasible or unethical (Wing et al., 2018). Prior studies have utilized this design to study the effects of ACA Medicaid expansion by comparing the changes in health outcomes between the expansion states (treatment group) and non-expansion states (control group), before and after the policy change (Wherry & Miller, 2016; Yue et al., 2018). Using 2010-2014 National Health Interview Survey data (NHIS) data, Wherry & Miller (2016) performed a DiD analysis to examine changes in health-related outcomes (e.g., insurance coverage, physician visits, hospitalizations, diabetes diagnosis, usual source of care, hypertension, cholesterol) in individuals 19-64 years living below 138% of the federal poverty level (FPL) residing in expansion states compared to those residing in non-expansion states. The study has found Medicaid expansion was associated with higher rates of health insurance coverage and increased utilization of some types of health care. A similar study of BRFSS data performed a DiD analysis to assess Medicaid expansion impact on access to primary care use in low-income adults. The study has found Medicaid expansion was associated with statistically significant gains in health insurance coverage, having personal doctors, and affordability (Yue et al., 2018).

Data Source

This study was deemed exempt from review by the investigator's Institutional Review Board. We used data from the 2010-2017 Medical Expenditure Panel Survey (MEPS). It provides national and regional level estimates on health insurance coverage, the frequency of healthcare utilization, the costs of these services, and sources of payment for the U.S. civilian noninstitutionalized population (AHRQ, 2018b). MEPS also collects data on respondents' health status, demographic and socio-economic characteristics, employment status, access to care, and comorbidities (AHRQ, 2018b). MEPS employs a panel design in which five rounds of interviews are collected over two full calendar years. As illustrated below, rounds one and two are conducted in year one. Round three begins in year one and is completed in year three. Rounds four and five are conducted in the subsequent year (Figure 3.1). The response rates for MEPS 2010-2017 range from 44.2% to 56.3% (AHRQ, n.d., 2019a).

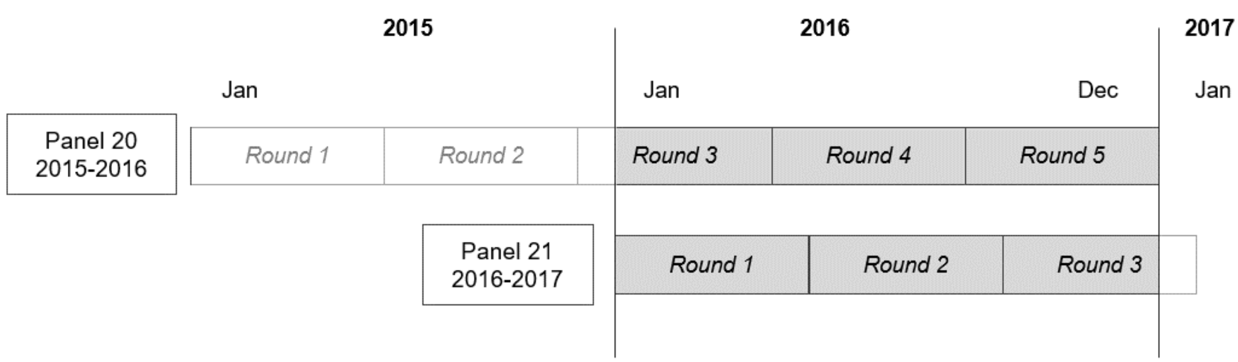

Figure 3.1. Schematic of Panels/Rounds for 2016 Calendar Year. Adopted from AHRQ (2018a).

The MEPS data consist of a subsample of households that participate in the National Health Interview Survey (NHIS) which is a nationally representative, cross-sectional household interview survey sponsored by the Centers for Disease Control and Prevention's National Center for Health Statistics (NCHS). With an annual response rate of approximately 70 percent, NHIS collects information throughout the year from the civilian, non-institutionalized population. NHIS contains information on household, family, and individual demographic characteristics, as well as income, health status and other healthcare related variables (CDC, 2019a).

The NHIS sampling employs an area probability, stratified multistage design (Parsons et al., 2014). An area probability sample includes geographic areas that are sampled with known probability (Lavrakas, 2008). In other words, each element in the sampling frame has a known, nonzero probability of being chosen (Groves et al., 2009, p. 98). Probabilities can be unequal in that some special populations (e.g., minorities) may have higher chances of being selected than others. This ensures that there are enough individuals included in the group to prepare separate estimates for the specified group (Groves et al., 2009, p. 98). For the 2008-2015 NHIS, black, Hispanic, and Asian persons are oversampled with adults aged 65 or older having a higher chance of being selected than other adults in the family (Parsons et al, 2014; CDC, 2019a).

The NHIS sampling frame encompasses housing units in place at the time of the 2000 U.S. Census (2008-2015 NHIS) and 2010 U.S. Census (2016 NHIS) (Parsons et al, 2014; CDC, 2019a). In the first stage of sampling, primary sampling units (PSUs) consisting of single counties or combined contiguous counties are selected from each state. PSUs are then stratified into Census-defined blocks based on the Census minority concentration status for implementing differential sampling rates (Parsons et al, 2014). Within each stratum secondary sampling units are formed consisting of clusters of an expected 8, 12, or 16 sample household units. From each housing unit, the interview process collects information on the family, sample child (if children are present), and sample adult (Parsons et al, 2014).

The MEPS has the same features of the NHIS complex survey design; but unlike the NHIS, college dorms represent ineligible housing units for MEPS. Analysis using MEPS data can be undertaken using either the individual or the family as the unit of analysis as a MEPS household may contain one or more family units, each consisting of one or more individuals (AHRQ, 2018b). MEPS is sampled from the previous year's NHIS responding households. For example, a full calendar year data file for 2016 will contain rounds 3-5 of Panel 20 (which uses the 2014 NHIS sampling frame) and rounds 1-3 of Panel 21 (which uses the 2015 NHIS sampling frame) (AHRQ, 2018a).

The Diabetes Care Survey is a component of MEPS that is administered to participants who answer a "yes" response to the survey question, "was the person ever told by a doctor or health professional that he/she had diabetes". The Diabetes Care Survey asks health related questions such as the number of times hemoglobin was checked, whether the person had feet, eyes, or blood pressure checked, and whether the person had an influenza vaccination. Additional questions assess whether the participant treats his/her diabetes with insulin, oral medications, or diet (AHRQ, 2018b).

For reasons of confidentiality, AHRQ restricts the use of certain MEPS variables including fully specified International Classification of Diseases (ninth revision) codes, fully specified industry and occupation codes, state and county federal information processing standards codes, census tract and block group codes, and federal and state marginal tax rates (AHRQ, 2019b). This study used restricted-access state identifiers in MEPS, and after approval by AHRQ, was performed in a NCHS Research Data Center. The RDC provides access to restricted-use data for statistical purposes while protecting the confidentiality of survey respondents, study subjects, or institutions (CDC, 2019b).

Study Population

Inclusion criteria consisted of individuals aged ≥18 years who were diagnosed with diabetes (n=21,612). Individuals who did not identify as non-Hispanic white, non-Hispanic black, or Hispanic were excluded (n=2,109). Individuals with missing data on eye examination (n=4,354), education (n=121), have usual source of care (n=118), insulin use (n=118), and duration of diabetes (n=412) were excluded from the study bringing the total analytic sample size to 14,380 observations. For Medicaid expansion analysis, the analyses were further restricted to individuals living below 138% of the FPL bring the analytic sample size to 4,790 observations.

Measures

Outcome Variable

The outcome for both research questions was operationalized by a survey question on whether “the respondent reported having an eye exam in which the pupils were dilated in the survey year”.

Main Independent Variables

The main independent variable for the first research question was race and ethnicity which included the categories of non-Hispanic white, non-Hispanic black, and Hispanic. The main independent variable for the second research question was operationalized based on whether an individual had resided in a state that expanded Medicaid and was conditional on when the state expanded. The expansion variable was coded as one (expansion) if the survey respondent’s residential state implemented Medicaid expansion prior to the respondent’s MEPS interview date. For example, for the states that implemented Medicaid expansion January 1, 2014, the treatment variable was coded as one if the interview occurred after this date. The expansion variable was coded zero (non-expansion) if the interview date had occurred before implementation of Medicaid expansion or if the respondent had resided in a state that did not expand Medicaid expansion during the study period. During the time of our study period (2010-2017), 31 states and the District of Columbia implemented Medicaid expansion and 19 states did not implement Medicaid expansion (Table 3.1).

Table 3.1

ACA Medicaid Expansion Date for Expansion States (KFF, 2019a)

Expansion States (*n=32)	
State	*Date of ACA Medicaid expansion*
Arizona, Arkansas, California, Colorado, Connecticut, District of Columbia, Delaware, Hawaii, Illinois Iowa, Kentucky, Maryland, Massachusetts, New York, North Dakota Ohio, Oregon, Rhode Island, Vermont, Washington, West Virginia	January 1, 2014
Michigan	April 1, 2014
New Hampshire	August 15, 2014
Indiana	February 1, 2015
Alaska	September 1, 2015
Pennsylvania	January 1, 2015
Montana	January 1, 2016
Louisiana	July 1, 2016
Non-expansion States (n=19)	
Alabama, Florida, Georgia, Idaho, Kansas, Maine, Mississippi, Missouri, Nebraska, North Carolina, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Wisconsin, Wyoming	

Note. *Includes the District of Columbia

Control Variables

As previously described in the literature review section, categorization of the control variables was informed by the Andersen Healthcare Utilization model. Predisposing factors included age, sex, marital status (married/ partnered or single/ never married/ widowed/ divorced/separated) and education (<12 years versus ≥12 years). Prior studies of individuals with diabetes have shown respondents who are older in age, female, married/partnered, and have a higher level of education are more likely to obtain eye examinations (Chen et al., 2014; Monnette et al., 2019; Shi et al., 2014). The enabling factors included economic status (living below 138% of FPL, living above 138% of FPL insurance status (insured, not insured), whether respondent has a usual source of care (yes/no), all which have been shown to be associated with receipt of eye care (Chen et al., 2014; Tran et al., 2017). Need factors included whether the individual takes insulin (yes/no) and duration of diabetes. As an indicator for diabetes severity, insulin use has been positively associated with eye examination use (Chen et al., 2014), and research has shown that duration of diabetes is positively associated with the diabetic retinopathy prevalence and thus, might influence eye examination utilization (ADA, 2019; Solomon et al., 2017; Zhao et al., 2014).

Statistical Analyses

All analyses were completed using Stata (version 16; StataCorp, College Station, TX). The *svyset* command was used to establish the survey design for the dataset. The MEPS design variables (STRATA and PSU) were used to account for the complex survey design and nonresponse and appropriate weights were applied to produce national estimates. Statistical significance was determined at $p<0.05$.

Trend Analyses (Research Question #1)

The study population included individuals aged 18 years or older who responded yes to “having ever been diagnosed with diabetes.” Descriptive statistics of the study population were calculated for each study year (2010-2017). Tests for trend were performed to determine if the study population characteristics changed over time. In crude analyses, weighted proportions of eye examination were generated for each survey year overall and by race and ethnicity. For each survey year, a Pearson's chi-squared test was performed to test differences in the proportion of eye examinations between each race and ethnicity group. Multivariable logistic regression models (controlling for the predisposing, enabling, and need factors) followed by the *margins* command were used to estimate adjusted prevalence of eye examinations and *margins dydx* was used to estimate marginal effects for each covariable.

Medicaid Expansion Analyses (Research Question #2)

The study population included U.S. adults with diabetes living below 138% of the FPL. Baseline study population characteristics were calculated separately for expansion versus non-expansion states for 2010 (base study year), 2014 (middle study year), and 2017 (last study year). A Pearson's chi-squared test was used to evaluate differences in characteristics of individuals residing in expansion and non-expansion states. A difference-in-difference (DiD) analysis was employed to estimate the effects of the ACA Medicaid expansion on eye examination rates. Prior studies have utilized this design to study the effects of ACA Medicaid expansion by comparing the changes in outcomes between the expansion group (treatment group) and non-expansion group (control group), before and after the policy change (Lee & Porell, 2018; Yue et al, 2018). We estimated the following logistic regression model:

$$\log[\mu_{ist}/1-\mu_{ist}]=\beta_0+\beta_1\text{Treatment}_{st}+\beta_2 X_{ist}+\lambda_t+\gamma_s$$

where $\log[\mu_{ist}/1-\mu_{ist}]$ is the outcome for individual *i* in state *s* with a survey date in year *t*. Treatment_{st} is a dummy variable equal to 1 for individuals residing in an expansion state at the time of the survey interview and 0 otherwise. λ_t represents the year fixed effects, which control for year-specific characteristics that may change over time, and γ_s represents state fixed effects, which control for state-specific time-invariant characteristics. X_{ist} is a vector of individual characteristics of respondents that include predisposing, enabling, and need factors. The DiD estimator (β_1) captured the change in outcome among individuals in Medicaid expansion states relative to individuals in non-expansion states after the expansion.

DiD relies on the assumption that pre-policy trends are similar in the treatment and control groups and any post-policy trends are attributable to the policy (Bertrand et al., 2003). This would hold true if changes in outcomes over time in each group differ by a fixed amount in every time period and exhibit a common set of period-specific changes (Wing et al., 2018). Therefore, any observed divergence between expansion and non-expansion states that occurs in post-policy years can be attributed to the impact of the ACA Medicaid expansions rather than a pre-existing differential trend (Wherry & Miller, 2016). When this assumption is violated, (e.g., when a change occurs in one group but not the other at the same time of the intervention), the resulting estimates will be biased. The following model was used to assess the parallel trend assumption:

$$\log[\mu_{ist}/1- \mu_{ist}] = \beta_0 + \beta_1 \text{Treatment}_{st} + \beta_2 \text{TR} + \beta_3 \text{Treatment}_{st} * \text{TR} + \beta_4 X_{ist}$$

where $\log[\mu_{ist}/1- \mu_{ist}]$ is the outcome for individual *i* in state *s* with a survey date in year *t.* Treatment_{st} is a dummy variable equal to 1 for individuals residing in an expansion state at the time of the survey interview and 0 otherwise. *TR* is a linear time trend for the period ending in 2013. X_{ist} is a vector of individual characteristics of respondents that includes predisposing, enabling, and need factors. The estimate for the interaction term between treatment and trend was found to be nonsignificant at (odds ratio [OR]:0.99, 95% confidence interval [CI]:0.97-1.01, p=0.585) suggesting no significant difference in pre-expansion trends between expansion and non-expansion states; this result supported the DiD parallel trends assumption.

CHAPTER 4-RESULTS

The chapter presents the results obtained from the data analysis. This study examined trends in eye examination rates among U.S. adults (aged≥18 years) with diabetes, assessed racial and ethnic differences in eye examination rates, and assessed changes in eye examination rates in individuals with diabetes living below 138% of the federal poverty level (FPL) in states that expanded Medicaid compared to those that did not using data from the 2010-2017 Medical Expenditure Panel Survey (MEPS). Sociodemographic and health-related characteristics are summarized in Table 4.1.

Description of Study Population

Majority of adults were non-Hispanic white (67.2%), 45-64 years of age (45.1%), women (50.5%), had ≥12 years education (80.1%), were married or partnered (56.5%), were living at or above 138% of the FPL (77.2%), were insured (93.3%), had a regular provider (93.3%), were non-insulin users (69.2%), and reported having diabetes for greater than 10 years (43.7%). Throughout the study years, the distribution of all characteristics remained the same with the exception of insurance status (p for trend <0.001), having a usual provider (p for trend =0.046), and duration of diabetes (p for trend <0.001). There was an overall downward trend in the crude rate of uninsured adults from 8.9% in 2010 to 6.1% in 2014 (p =0.003) to 4.1% in 2017 (p=0.019) (see **Appendix A**). The proportion of adults with a usual provider was not stable across years with the lowest percentages of 92.6% reported in 2012 and 92.5% reported in 2013 and the highest percentages of 94.4% reported in 2011 and 94.5% reported in 2014 (see **Appendix B**). There was an overall downward trend in the percentage of adults who had a diabetes duration of 0-5 years from 36.8% in 2010 to 28.5% in 2017, and an upward trend in the percentage of adults who had a diabetes duration greater than 10 years from 43.7% in 2010 to

50.2% in 2017. The percentage of adults with diabetes for 6-10 years remained relatively stable at 22.8% in 2010 and 21.4% in 2017 (see **Appendix C**).

Table 4.1

Characteristics of Adults with Diabetes in the U.S.: 2010-2017 MEPS

	All Years n (%)	**2010** n (%)	**2011** n (%)	**2012** n (%)	**2013** n (%)	**2014** n (%)	**2015** n (%)	**2016** n (%)	**2017** n (%)
Total Sample	14380	1594	1762	1947	1820	1775	1807	1828	1847
Eye Examination	8980 (65.5)	990 (65.7)	1103 (65.7)	1222 (66.6)	1107 (65.1)	1103 (65.3)	1143 (65.7)	1137 (65.2)	1175 (64.9)
Race and Ethnicity									
NH-white	6420 (67.2)	777 (69.0)	835 (67.1)	810 (66.7)	747 (68.0)	745 (67.8)	772 (65.9)	804 (66.8)	930 (66.5)
NH-black	3866 (16.3)	416 (16.1)	486 (16.9)	550 (16.2)	525 (16.1)	509 (16.0)	494 (16.9)	460 (15.9)	426 (16.5)
Hispanic	4094 (16.5)	401 (14.8)	441 (16.0)	587 (17.1)	548 (15.9)	521 (16.2)	541 (17.2)	564 (17.2)	491 (17.0)
Age Group									
18 to 44 years	1948 (11.8)	239 (13.8)	270 (14.1)	280 (12.0)	249 (11.0)	238 (10.9)	233 (10.9)	235 (11.3)	204 (10.8)
45 to 64 years	6724 (45.1)	770 (47.2)	830 (47.4)	903 (44.7)	867 (44.3)	814 (43.1)	853 (45.3)	867 (45.2)	820 (44.1)
>=65 years	5708 (43.1)	585 (38.0)	662 (38.5)	764 (43.3)	704 (44.7)	723 (46.0)	721 (43.8)	726 (43.6)	823 (45.2)
Sex									
Men	6475 (49.5)	696 (49.3)	788 (50.8)	907 (50.8)	838 (50.0)	761 (46.9)	800 (48.4)	829 (49.3)	856 (50.9)
Women	7905 (50.5)	898 (50.7)	974 (49.2)	1040 (49.2)	982 (50.0)	1014 (53.1)	1007 (51.6)	999 (50.7)	991 (49.1)
Education									
<12 years	4090 (19.9)	475 (21.5)	541 (21.5)	554 (20.9)	557 (20.6)	481 (17.9)	490 (18.2)	516 (19.3)	476 (19.7)
≥12 years	10390 (80.1)	1119 (78.5)	1221 (78.5)	1393 (79.1)	1263 (79.4)	1294 (82.1)	1317 (81.8)	1312 (80.7)	1371 (80.3)
Marital Status									
Married/partnered	7528 (56.5)	832 (57.3)	882 (56.0)	997 (56.6)	933 (56.3)	877 (56.4)	937 (59.3)	907 (56.8)	893 (53.0)
Single	7122 (43.5)	762 (42.7)	880 (44.0)	950 (43.4)	887 (43.7)	898 (43.6)	870 (40.7)	921 (43.2)	954 (47.0)
Economic Status									
<138% FPL	4794 (22.8)	524 (23.8)	586 (22.6)	677 (23.8)	616 (22.7)	632 (25.3)	586 (21.2)	601 (21.5)	575 (22.1)
≥138% FPL	9583 (77.2)	1070 (76.2)	1176 (77.4)	1270 (76.2)	1204 (77.3)	1143 (74.7)	1221 (78.8)	1227 (78.5)	1272 (77.9)
*Insured									
Uninsured	1289 (6.7)	187 (8.9)	212 (8.4)	238 (8.2)	209 (8.2)	167 (6.1)	135 (5.0)	143 (5.3)	98 (4.1)
Insured	12991 (93.3)	1407 (91.1)	1550 (91.6)	1709 (91.8)	1611 (91.8)	1608 (93.9)	1672 (95.0)	1685 (94.7)	1749 (95.9)
*Has Usual Provider									
Yes	13234 (93.3)	1470 (93.3)	1626 (94.4)	1763 (92.6)	1660 (92.5)	1660 (94.9)	1670 (93.4)	1677 (92.7)	1708 (92.8)
No	1146 (6.7)	124 (6.7)	136 (5.6)	184 (7.4)	160 (7.5)	115 (5.1)	137 (6.6)	151 (7.3)	139 (7.2)
Takes Insulin									
Yes	4570 (30.8)	493 (30.7)	571 (32.5)	651 (32.1)	589 (30.5)	554 (30.5)	549 (29.9)	578 (30.3)	585 (30.3)
No	9810 (69.2)	1101 (69.3)	1191 (67.5)	1296 (67.9)	1231 (69.5)	1221 (69.5)	1258 (70.1)	1250 (69.7)	1262 (69.7)
*Diabetes Duration									
0-5 years	4851 (33.5)	573 (36.8)	644 (35.8)	695 (35.2)	642 (35.4)	598 (34.1)	593 (33.1)	568 (30.4)	538 (28.5)
6-10 years	3257 (22.8)	391 (24.9)	399 (22.4)	443 (22.7)	420 (23.7)	402 (22.8)	389 (21.2)	418 (23.4)	395 (21.4)
>10 years	6272 (43.7)	630 (38.3)	719 (41.8)	809 (42.1)	758 (40.9)	775 (43.1)	825 (45.6)	842 (46.2)	914 (50.2)

Note. Table reports unweighted n's. *Significant for linear trend at p<0.05. NH, non-Hispanic; FPL, federal poverty level.

Crude Trends and Racial and Ethnic Differences in Eye Examination Rates

Across 2010-2017, there were no significant changes in the overall study population's crude eye examination rates of (p for trend=0.995) (Figure 4.1). Throughout the 8-year study period, on average 65.5% (95% CI: 64.3-66.7) of U.S. adults with diabetes received an eye examination (Table 4.1). In 2010, the overall study population's crude eye examination rate was 65.7% (95% CI: 62.9-68.5) which did not significantly differ from the 2014 (middle study year) rate (65.3%, 95% CI: 62.2-68.3, p=0.084) or from the 2017 rate (64.9%, 95% CI: 62.1-67.5, p=0.667). Similarly, no significant trends were noted among non-Hispanic whites, non-Hispanic blacks, and Hispanics (p for trend=0.984, 0.674, and 0.419, respectively) (Figure 4.1).

Figure 4.1

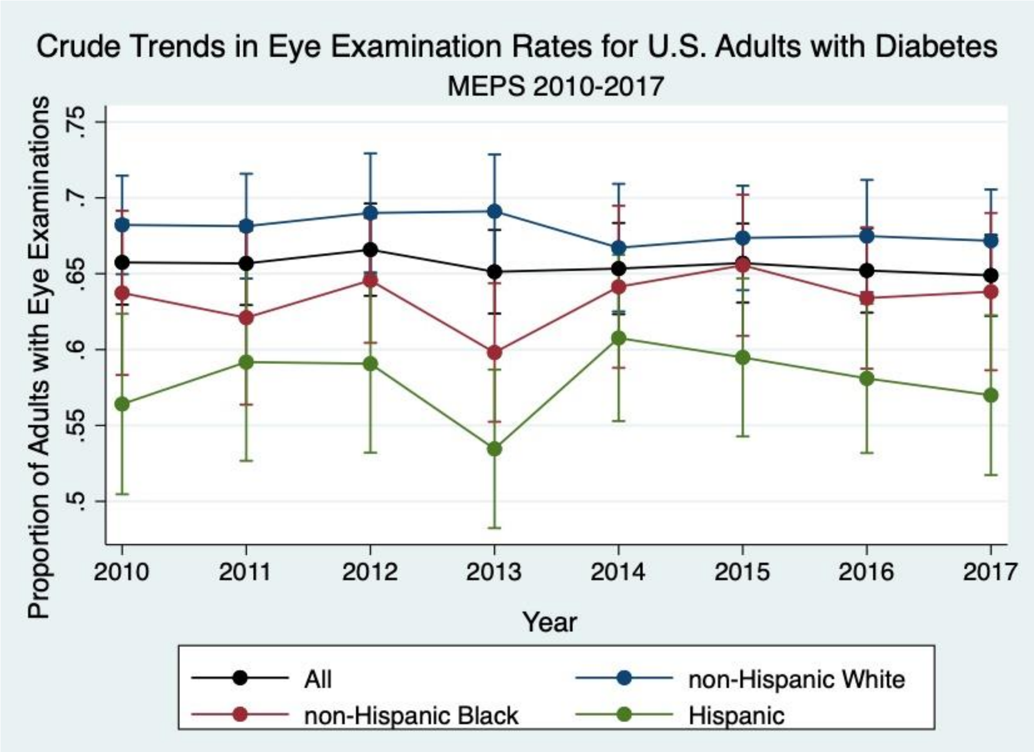

Figure 4.1. Crude trends in eye examination rates among U.S. adults (age ≥18 years) with diabetes: MEPS 2010-2017. Error bars represent 95% confidence intervals.

In examining differences in crude eye examination rates by race and ethnicity, there were statistically significant differences in the average crude eye examination rates for Hispanics compared to non-Hispanic whites (58.0%, 95% CI: 55.7-60.2 vs 67.8%, 95% CI: 66.2-69.5, p<0.001); non-Hispanic blacks compared to non-Hispanic whites (63.4%, 95% CI: 61.4-65.5 vs 67.8%, 95% CI: 66.2-69.5, p<0.001); and Hispanics compared to non-Hispanic blacks (58.0%, 95% CI: 55.7-60.2 vs 63.4%, 95% CI: 61.4-65.5, p<0.001). Except for 2014, a significant difference in eye examination rates persisted between non-Hispanic whites and Hispanics throughout the study period (Figure 4.1).

Adjusted Trends and Racial and Ethnic Differences in Eye Examination Rates

Multivariable logistic regression models were used to assess trends and examine racial and ethnic differences in eye examination rates while controlling for year and state fixed effects, predisposing factors, enabling factors, and need factors (Table 4.2). When controlling for the predisposing factors (i.e., age, sex, education, marital status), the average adjusted rates for eye examination for the overall population did not significantly change throughout the study period (66.5%, 95% CI: 63.9-69.1 for 2010 vs 65.0%, 95% CI: 62.0-67.3 for 2017) (p for trend=0.913). The average adjusted rate of eye examination for Hispanics was 2.9 percentage points lower than that of non-Hispanic whites (65.9%, 95% CI: 64.3-67.7, p=0.047). For each study year, the adjusted rate of eye examination for Hispanics was significantly lower than that of non-Hispanic whites. No significant differences were seen in adjusted eye examination rates between non-Hispanic whites and non-Hispanic blacks for any of the study years (Figure 4.2a).

In the model adjusting for enabling factors (i.e., insurance status, have a usual provider, and economic status), the average adjusted rates for eye examination for the overall population remained relatively unchanged throughout the study period (66.2%, 95% CI: 63.7-68.9 for 2010 vs 64.3, 95% CI: 61.5-66.9 for 2017) (p for trend=0.931). The average adjusted rate of eye examination for non-Hispanic whites was 2.7 percentage points and 4.7 percentage points higher than those of non-Hispanic blacks (64.0%, 95% CI: 62.1-65.9, p=0.029) and Hispanics (61.9%, 95% CI: 59.6-64.3, p=<.001), respectively (Table 4.2). For each study year, the adjusted rate of eye examination for non-Hispanic whites was higher than that of non-Hispanic blacks and Hispanics (Figure 4.2b).

The average adjusted eye examination rates for the overall population in the model controlling for need factors (i.e., insulin use and duration of diabetes) did not significantly change throughout the study period (66.2%, 95% CI: 63.5-68.9 for 2010 vs 64.0, 95% CI: 61.4-66.7 for 2017) (p for trend=0.939). For combined study years, the average adjusted rate of eye examination significantly differed among the races and ethnicities. The average adjusted eye examination rates for non-Hispanic whites was 4.5 percentage points and 9.5 percentage points higher than those of non-Hispanic blacks (63.3%, 95% CI: 61.3-65.4, p<.001) and Hispanics (58.2%, 95% CI: 56.1-60.5, p<.001), respectively (Table 4.2). For each study year, the adjusted rate of eye examination for non-Hispanic whites was higher than that of non-Hispanic blacks and Hispanics (Figure 4.2c).

In the model controlling for all predisposing, enabling, and need factors, although a downward trend was seen in eye examination rates, the average adjusted eye examination rates for the overall population did not significantly change throughout the study period (67.3%, 95% CI: 64.8-69.8 for 2010 vs 63.8, 95% CI: 61.2-66.5 for 2017) (p for trend=0.562) (see **Appendix D**). Adjusting for all factors eliminated any previous significant differences seen in eye examination rates between non-Hispanic whites and non-Hispanic blacks and non-Hispanic whites and Hispanics (Table 4.2, Figure 4.2d).

Additional fully adjusted models were estimated to assess interactions between race and ethnicity and insurance status, as well as race and ethnicity and income. Analyses revealed that there was a different relationship between race and ethnicity and receipt of eye examination for those who are insured compared to those who are not insured. The difference in eye examination rates between insured compared to uninsured was significantly higher for non-Hispanic whites (67.0%, 95% CI: 65.4-68.6 vs 44.4%, 95% CI: 38.1-50.6, $p<.001$), followed by non-Hispanic blacks (66.7%, 95% CI: 64.8-68.7 vs 50.6%, 95% CI: 44.0-57.1, $p<.001$), and Hispanics (65.6%, 95% CI: 63.1-68.0 vs 53.0%, 95% CI: 48.0-58.0, $p<.001$) (see **Appendix E**). When assessing the interaction between race and ethnicity and income, the difference in eye examination rate between those with incomes ≥138% FPL compared to those with incomes <138% FPL was significantly higher for non-Hispanic whites (66.8%, 95% CI: 65.1-68.5 vs 61.1%, 95% CI: 58.4-63.8, $p<0.001$); no significant differences were seen in non-Hispanic blacks or Hispanics (see **Appendix F**).

A likelihood ratio test was used to evaluate differences between the predisposing, enabling, need, and full models to identify the model which fit the data the best. Based on the results of the likelihood ratio test, the full model had the better fit compared to each of the smaller models (models with predisposing, enabling, and need factors; each $p<0.001$) (see **Appendix G**).

Table 4.2

Adjusted Prevalence of Eye Examination Among U.S. Adults with Diabetes: 2010-2017 MEPS

	Model with Predisposing Factors			Model with Enabling Factors			Model with Need Factors			Full Model		
	AAP, %	95% CI	P-value	AAP, %	95% CI	P-value	AAP, %	95% CI	P-value	AAP, %	95% CI	P-value
Year												
2010	66.5	63.9-69.1	ref.	66.2	63.7-68.9	ref.	66.2	63.5-68.9	ref.	67.3	64.8-69.8	ref.
2011	66.7	64.1-69.4	0.889	65.8	63.1-68.6	0.830	65.9	63.2-68.5	0.853	66.8	64.2-69.4	0.751
2012	66.7	63.8-69.5	0.937	67.1	64.2-70.0	0.629	66.8	63.9-69.7	0.752	67.2	64.4-69.9	0.937
2013	64.8	62.1-67.5	0.375	65.5	62.9-68.3	0.721	65.4	62.7-68.1	0.663	65.6	63.0-68.2	0.351
2014	64.5	61.5-67.5	0.324	65.0	62.2-67.9	0.555	65.4	62.5-68.4	0.684	64.6	61.7-67.4	0.170
2015	65.1	62.4-67.6	0.440	65.1	62.5-67.6	0.569	65.6	63.1-68.2	0.771	64.8	62.3-67.2	0.152
2016	65.0	62.2-67.7	0.429	65.9	62.1-67.6	0.495	64.8	61.9-67.5	0.471	64.6	61.8-67.3	0.152
2017	65.0	62.0-67.3	0.340	64.3	61.5-66.9	0.307	64.0	61.4-66.7	0.259	63.8	61.2-66.5	0.059
Race and Ethnicity												
NH-White	65.9	64.3-67.6	ref.	66.7	64.1-68.2	ref.	67.7	66.2-69.4	ref.	65.6	64.1-67.1	ref.
NH-Black	65.8	63.8-67.7	0.880	**64.0**	**62.1-65.9**	**0.029**	**63.3**	**61.3-65.4**	**<.001**	65.6	63.7-67.5	0.960
Hispanic	**63.1**	**60.9-65.4**	**0.047**	**61.9**	**59.6-64.3**	**<.001**	**58.2**	**56.1-60.5**	**<.001**	65.1	62.8-67.3	0.734
Age												
18 to 44 years	49.6	46.2-52.8	ref.							53.5	50.1-56.7	ref.
45 to 64 years	**60.5**	**58.8-62.1**	**<.001**							**62.1**	**60.5-63.4**	**<.001**
>=65 years	**74.7**	**73.1-76.3**	**<.001**							**72.4**	**70.1-74.0**	**<.001**
Sex												
Men	64.5	62.9-66.1	ref.							64.7	63.266.1	ref.
Women	66.3	64.7-67.8	0.082							66.3	64.8-67.8	0.094
Education												
<12 years	56.3	54.0-58.5	ref.							57.6	55.4-59.9	ref.
≥12 years	**67.8**	**66.5-69.1**	**<.001**							**67.5**	**66.2-68.7**	**<.001**
Marital Status												
Single	61.4	59.8-63.1	ref.							61.9	60.3-63.6	ref.
Married/partnered	**68.6**	**67.1-70.0**	**<.001**							**68.3**	**66.8-69.6**	**<.001**
Economic status												
<138% FPL				60.8	58.8-62.8	ref.				62.9	61.1-64.8	ref.
≥138% FPL				**66.8**	**65.5-68.2**	**<.001**				**66.2**	**65.1-67.5**	**0.002**
Has Usual Provider												
No				50.3	46.1-54.5	ref.				54.5	50.5-58.6	ref.
Yes				**66.5**	**65.3-67.7**	**<.001**				**66.3**	**65.2-67.4**	**<.001**

	Model with Predisposing Factors			Model with Enabling Factors			Model with Need Factors			Full Model		
	AAP, %	95% CI	P-value	AAP, %	95% CI	P-value	AAP, %	95% CI	P-value	AAP, %	95% CI	P-value
Insurance Status												
Uninsured				42.2	38.4-45.8	ref.				48.9	45.0-52.7	ref.
Insured				**67.1**	**65.9-68.4**	**<.001**				**66.7**	**65.5-67.9**	**<.001**
Takes insulin												
No							63.5	62.2-65.1	ref.	62.9	70.0-73.2	ref.
Yes							**70.0**	**68.2-71.7**	**<.001**	**71.6**	**61.5-64.3**	**<.001**
Diabetes Duration												
0-5 years							55.8	53.7-57.7	ref.	58.8	56.8-60.7	ref.
6-10 years							**67.4**	**64.9-69.7**	**<.001**	**67.3**	**65.0-69.6**	**<.001**
>10 years	66.5	63.9-69.1	ref.	66.2	63.7-68.9	ref.	**72.1**	**70.6-73.7**	**<.001**	**70.0**	**68.5-71.6**	**<.001**

Note. Reference groups are year=2010, race/ethnicity=NH-whites, age=18-44 years, men, education= ≤12 years, marital status=single, economic status=<138% FPL, usual provider=no, insurance status=uninsured, insulin use=no, and duration of diabetes=0-5 years. Bold font indicates statistical significance at P<0.05. AAP, average adjusted prediction; NH, non-Hispanic; CI, confidence interval; ref, reference; FPL, federal poverty level.

Figure 4.2

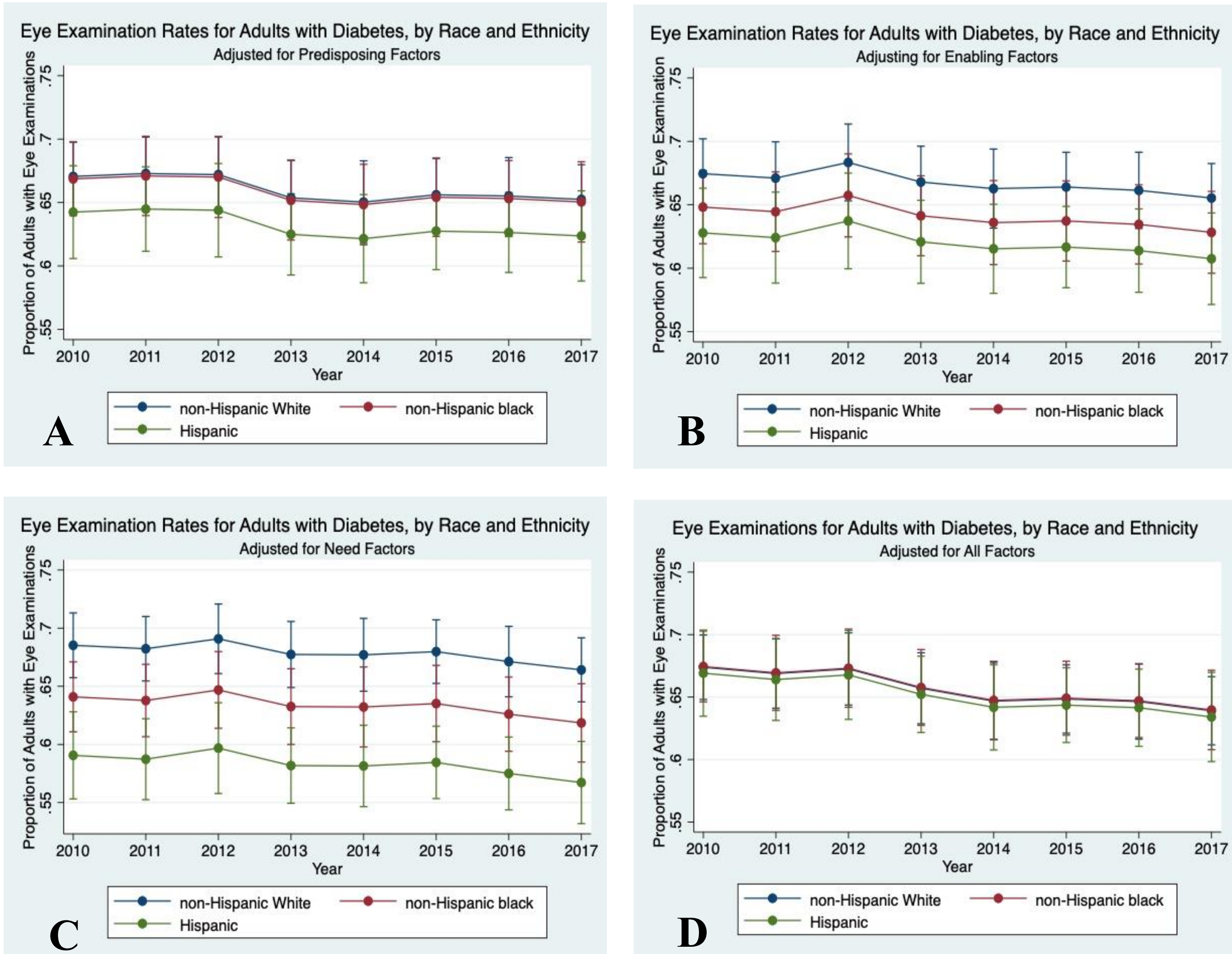

Figure 4.2. Adjusted trends in eye examination rates among U.S. adults (age ≥18 years) with diabetes: MEPS 2010-2017. Error bars represent 95% confidence intervals.

Medicaid Expansion Analyses

For Medicaid Expansion analysis, we restricted our study population to adults with diabetes living below 138% of the FPL. The aforementioned adjusted analysis demonstrated a significant difference in eye examination rates between adults living at or above 138% of the FPL compared to adults living below 138% of the FPL. The former had 3.3 percentage points (95% CI: 1.2-5.4) higher eye examination rates compared to the latter ($p=0.002$) (Table 4.2).

The characteristics of U.S. adults with diabetes living below 138% of the FPL are summarized for 2010 (base study year), 2014 (middle study year), and 2017 (last study year) by expansion status (Table 4.3). In 2010, the distribution of all characteristics did not significantly differ between individuals residing in never-expanding states and states that expanded Medicaid later on. With the exception of insurance status, no significant differences were observed for 2014 and 2017. Fewer individuals residing in expansion states reported being uninsured compared to individuals residing in non-expansion states in 2014 (5.4% vs 15.1%, $p=0.001$) and in 2017 (2.6% vs 11.0%, $p<0.001$). By the end of 2014, 26 states and the District of Columbia expanded Medicaid representing 45.7% of the study population, and as of the end of 2017, 31 states and the District of Columbia expanded Medicaid representing 52.4% of the study population (Table 4.3).

Table 4.3

Characteristics of Adults with Diabetes Living below 138 % of the Federal Poverty Level, by Medicaid Expansion Status

	2010 (n=524)			2014 (n=632)			2017 (n=575)		
	Expansion n (%)	Non-expansion n (%)	P-value	Expansion n (%)	Non-expansion n (%)	P-value	Expansion n (%)	Non-expansion n (%)	P-value
Eye examination	167 (62.2)	140 (57.1)	0.310	185 (56.2)	186 (62.1)	0.249	182 (61.4)	151 (52.2)	0.071
Race/ethnicity			0.571			0.261			0.022
NH-white	106 (55.0)	75 (50.4)		97 (55.4)	85 (52.9)		125 (53.8)	89 (49.4)	
NH-black	69 (17.8)	90 (23.4)		87 (16.6)	128 (25.1)		64 (20.1)	111 (32.7)	
Hispanic	110 (27.3)	74 (26.2)		148 (27.9)	87 (22.0)		105 (25.1)	81 (18.0)	
Age group			0.344			0.057			0.651
18 to 44 years	47 (14.0)	47 (19.8)		71 (16.9)	36 (8.2)		45 (15.6)	29 (14.0)	
45 to 64 years	133 (47.4)	113 (47.0)		140 (42.4)	138 (43.9)		125 (40.8)	126 (45.7)	
>=65 years	105 (38.6)	79 (33.2)		121 (40.7)	126 (47.8)		124 (43.6)	126 (40.3)	
Sex			0.308			0.491			0.085
Men	99 (38.5)	72 (33.8)		111 (38.2)	108 (35.2)		107 (40.7)	86 (32.1)	
Women	186 (61.5)	167 (66.2)		413 (63.1)	192 (64.8)		187 (59.3)	195 (67.9)	
Education			0.103			0.254			0.295
<12 years	131 (37.7)	127 (37.7)		181 (61.0)	179 (66.3)		183 (66.6)	170 (71.7)	
≥12 years	154 (62.3)	112 (51.9)		151 (39)	121 (33.7)		111 (33.4)	111 (28.2)	
Marital Status			0.412			0.603			0.745
Married/partnered	100 (31.9)	80 (36.6)		110 (37.0)	100 (33.9)		80 (28.1)	75 (26.6)	
Single	185 (68.1)	159 (63.4)		222 (63.1)	200 (66.1)		214 (71.9)	206 (73.4)	
Insurance Status			0.129			0.001			<.001
Uninsured	45 (11.8)	44 (17.0)		31 (5.4)	51 (15.1)		10 (2.6)	29 (11.0)	
Insured	240 (88.2)	195 (83.0)		301 (94.6)	249 (84.9)		284 (97.5)	252 (88.9)	
Has regular provider			0.441			0.587			0.109
Yes	257 (91.2)	218 (92.9)		305 (93.2)	280 (94.5)		272 (93.4)	254 (88.9)	
No	28 (8.7)	21 (7.1)		27 (6.8)	20 (5.5)		22 (6.6)	27 (11.1)	
Takes insulin			0.975			0.090			0.249
Yes	94 (33.5)	84 (33.4)		118 (40.7)	110 (32.3)		96 (32.3)	107 (37.6)	
No	191 (66.4)	155 (66.6)		214 (59.3)	190 (67.7)		198 (67.7)	174 (62.4)	

	2010 (n=524)			2014 (n=632)			2017 (n=575)		
	Expansion n (%)	Non-expansion n (%)	P-value	Expansion n (%)	Non-expansion n (%)	P-value	Expansion n (%)	Non-expansion n (%)	P-value
Diabetes duration group			0.713			0.559			0.572
0-5 years	97 (34.5)	86 (36.8)		112 (33.7)	98 (30.6)		86 (25.2)	80 (27.9)	
6-10 years	73 (34.7)	63 (26.8)		68 (21.9)	72 (26.4)		60 (21.2)	52 (17.3)	
>10 years	115 (40.9)	90 (36.4)		152 (44.4)	130 (43.0)		148 (53.6)	149 (54.8)	
*Expansion status, # states (% of population)	0 (0.0)	51 (100.0)		27 (45.7)	24 (54.3)		32 (52.4)	19 (47.6)	

Note: Table reports unweighted n's. * Includes the District of Columbia. NH, non-Hispanic

Five multivariable logistic regression models were used to estimate treatment effects. The first model (and each subsequent model) included the treatment dummy variable and controlled for state and year fixed effects. The second, third, and fourth models were adjusted for predisposing, enabling, and need factors, respectively, and the fifth model was adjusted for all factors.

Based on the results of the first model, the adjusted prevalence of eye examination rates among the study population residing in states that expanded Medicaid was 2.4 percentage points lower than the rate of those residing in states that did not expand; however, this difference was not statistically significant (p=0.547) (Table 4.4). Similar nonsignificant results were seen for the second (predisposing), third (enabling), and fourth (need) models in that the study population residing in the states that expanded had a lower adjusted prevalence of examinations than those residing in the states that did not expand (model 2: -2.1 percentage points change, p=0.571; model 3: -2.5 percentage points change, p=0.513; and model 4: -3.2, p=0.399). The fully adjusted model also did not find any statistically significant differences in the adjusted prevalence of eye examination rates in states that expanded versus states that did not expand Medicaid (59.4, 95% CI: 56.8-62.1 vs 56.4, 95% CI: 50.9-62.0, p=0.413) (Table 4.4). Further, no significant interaction was seen between expansion status and race and ethnicity which suggests that changes in eye examination rates did not significantly differ in expansion versus non-expansion states for non-Hispanic whites (-6.0 percentage points change, p=0.210), non-Hispanic blacks (1.6 percentage points change, p=0781) and Hispanics (-2.0 percentage points change, p=0.698).

A likelihood ratio test was used to evaluate differences between the predisposing, enabling, need, and full models to identify the model which fit the data the best. Based on the results of the likelihood ratio test, the full model had the better fit compared to each of the smaller models (models with predisposing, enabling, and need factors; each p<0.001) (see **Appendix G**).

Sensitivity analyses were performed to examine whether changes in eye examination rates differed by level of exposure to Medicaid expansion. Three different treatment variables were used in fully adjusted models: 1) years since expansion modeled as a continuous variable, 2) treatment with a 1-year post-expansion lag, and 3) treatment with a 2-year post-expansion lag. We did not find any significant changes in eye examination rates for any of the treatment variables (model 1-OR:1.1, 95% CI: 0.9-1.2, P=0.346; model 2-OR:1.1, 95% CI: 0.8-1.6, p=0.508; model 3-OR: 1.3, 95 % CI: 0.9-1.8, P=0.099 (see **Appendix H**).

Table 4.4

Changes in Eye Examination Rates among Diabetic Respondents Living below 138% of the Federal Poverty Line, Before and After Medicaid Expansion

	Model 1			Model 2			Model 3			Model 4			Model 5		
	AAP	95% CI	P-value	AAP	95% CI	P-value	AAP	95% CI	P-value	AAP	95% CI	P-value	AAP	95% CI	P-value
Treatment Effects															
Non-Expansion	59.3	56.4-62.1	ref.	59.2	56.4-61.9	ref.	59.3	56.5-62.1	ref.	59.5	56.7-62.2	ref.	59.4	56.8-62.1	ref.
Expansion	56.8	50.9-62.7	0.547	57.1	51.4-62.7	0.572	56.8	51.0-62.5	0.513	56.3	50.5-62.0	0.399	56.4	50.9-62.0	0.413
Race and ethnicity															
NH white				57.9	54.9-60.8	ref.							57.5	54.7-60.2	ref.
NH black				59.9	56.5-63.3	0.397							59.2	55.7-62.6	0.477
Hispanic				58.9	55.2-62.7	0.666							60.4	56.6-64.2	0.242
Age															
18 to 44 years				44.5	40.1-49.1	ref.							49.2	44.4-53.9	ref.
45 to 64 years				**53.8**	**51.2-56.4**	**<.001**							**55.4**	**52.8-58.0**	**<.001**
>=65 years				**69.6**	**66.8-72.4**	**<.001**							**55.1**	**63.2-69.0**	**<.001**
Sex															
Men				56.3	53.4-59.2	ref.							57.1	54.2-59.8	ref.
Women				**60.1**	**57.8-62.4**	**0.036**							59.6	57.4-61.7	0.138
Education															
<12 years				54.3	51.3-57.2	ref.							54.6	51.6-57.4	ref.
≥12 years				**61.2**	**58.9-63.4**	**<.001**							**61.1**	**58.9-63.1**	**<.001**
Marital Status															
Married/partnered				61.1	58.1-64.1	ref.							61.7	58.7-64.6	ref.
Single				57.3	54.9-59.7	0.058							**57.1**	**54.8-59.4**	**0.017**
Has Usual Provider															
No							43.3	37.3-49.3	ref.				47.6	41.4-53.8	ref.
Yes							**60.2**	**58.2-62.1**	**<.001**				**59.7**	**57.9-61.7**	**<.001**
Insurance Status															
Uninsured							38.8	33.4-44.1	ref.				44.7	39.1-50.3	ref.
Insured							**61.1**	**59.1-63.2**	**<.001**				**60.4**	**58.4-62.5**	**<.001**
Takes Insulin															
No										56.8	54.4-59.2	ref.	56.2	54.1-58.4	ref.
Yes										**61.9**	**58.9-64.9**	**0.008**	**62.9**	**60.0-65.8**	**<.001**
Diabetes Duration															
0-5 years										48.4	45.4-51.4	ref.	51.9	48.9-55.0	ref.
6-10 years										56.0	52.2-59.8	<.001	56.5	52.7-60.3	0.057
>10 years										**67.4**	**64.7-69.9**	**<.001**	**64.7**	**62.1-67.3**	**<.001**

Note. Reference groups are year=2010, race/ethnicity=NH-whites, age=18-44 years, men, education= ≤12 years, marital status=single, usual provider=no, insurance status=uninsured, insulin use=no, and duration of diabetes=0-5 years. Bold font indicates statistical significance at P<0.05. All models adjust for state and year fixed effects. Model 2 adjust for predisposing factors. Model 3 adjusts for enabling factors. Model 4 adjusts for need factors. Model 5 adjusts for all factors. NH, non-Hispanic; CI, confidence interval; AAP, average adjusted predictions; ref, reference.

CHAPTER 5-DISCUSSION

This chapter summarizes findings and places them in the context of existing and future state of research and practice, given the study's limitations and strengths. This research examined trends in eye examinations among U.S. adults (aged≥18 years) with diabetes, assessed racial and ethnic differences in eye examination rates, and assessed changes in eye examination rates in individuals with diabetes living below 138% of the federal poverty level (FPL) in states that expanded Medicaid compared to those that did not. This study utilized data from the 2010-2017 Medical Expenditure Panel Survey. Trend analyses and multivariable logistic regression analyses were used to answer two specific research questions: (1) Are there racial and ethnic disparities in eye examination rates among U.S. adults (age≥18 years) with diabetes across 2010-2017? (2) Is ACA Medicaid expansion associated with changes in eye examination rates among U.S. adults with diabetes living below 138% of the federal poverty level (FPL)?

Summary of Findings

Crude Trends and Racial and Ethnic Differences in Eye Examination Rates

Studies on recent trends in eye examination rates examined by race and ethnicity are scarce in the literature. To the best of our knowledge, the present study is the first to examine trends in racial and ethnic disparities in eye examination rates among U.S. adults (age≥18 years) with diabetes across 2010-2017. This study found no significant trends in crude eye examination rates for the overall study population or for non-Hispanic whites, non-Hispanic blacks, and Hispanics. Similarly, a study based on data from the 2001-2010 Behavioral Risk Factor Surveillance System (BRFSS) also found no significant trends in crude eye examination rates for the overall population, non-Hispanic blacks, or Hispanics, but found an overall decreasing trend in eye examination rates for non-Hispanic whites (Chen et al., 2014). Shi et al. (2014) found the opposite in their study based on 2002-2009 MEPS data: non-Hispanic whites had a significant upward trend in eye examination rates. The overall crude eye examination rates of 60-

67% reported in their study is consistent with our study's rates of 64-66% indicating that the annual eye screening rates have remained relatively stable over time.

In unadjusted analysis of racial and ethnic differences in eye examination rates, the present study found that overall, the crude eye examination rate in non-Hispanic whites was significantly higher than the crude eye examination rates in non-Hispanic blacks and Hispanics. The findings in this study are similar to those of other studies in that crude eye examination rates were higher for non-Hispanic whites compared to Hispanics (Lee et al., 2006; Shi et al., 2014) and for non-Hispanic whites compared to non-Hispanic blacks (Lee et al., 2006; Shi et al., 2014).

Adjusted Trends and Racial and Ethnic Differences In Eye Examination Rates

This study used multivariable logistic regression to control for predisposing, enabling, and need factors while assessing trends and racial and ethnic differences in eye examination rates. Similar to unadjusted analysis, adjusted analyses found no significant trends in eye examination rates for the overall population or for non-Hispanic whites, non-Hispanic blacks, and Hispanics.

In the models adjusting for enabling and need factors, non-Hispanic blacks and Hispanics were less likely to report eye examinations compared to non-Hispanic whites. However, in the model adjusting for predisposing factors, Hispanics were the only group less likely to report eye examinations compared to non-Hispanic whites. This suggest that the predisposing model contains confounding factors that distort the relationship between the race and ethnicity and eye examination rates due to 1) their association with eye examination rates and 2) their uneven distribution among the racial and ethnic groups. For example, research has shown that black Americans display lower marriage rates than do other racial and ethnic groups (Bramlett & Mosher, 2001; Martin et al., 2014; Raley et al., 2015; Sweeny & Phillips, 2004) and high school dropout rates remain the highest among Latinos, followed by African-Americans and then Whites (Kena et al., 2015). Our findings support this research in that a greater proportion of Hispanics (45.7%) had <12 years education compared to non-Hispanic whites (13.5%) or non-Hispanic blacks (19.9%) and a greater proportion of non-Hispanic blacks (60.6%) were single compared to non-Hispanics whites (39.4) and Hispanics (43.6%) (see **Appendix I**). Additionally, both education and marital status were significantly associated with the outcome in adjusted models. Specifically, adults who were married had a 6.3 pps higher rate of eye examination compared to adults who were single (p=<.001) and adults with ≥12 years of education had a 9.8 pps higher rate of eye examination compared to adults with <12 years of education (p=<.001; Table 4.2). Therefore, in controlling for these factors, a more accurate relationship between and ethnicity and receipt eye examination can be observed.

In the model adjusting for all factors (predisposing, enabling, and need), no significant differences were found in eye examination rates by race and ethnicity. Our findings are consistent with Monnette et al.'s (2014) study of 2014-2015 MEPS data which also did not find significant differences in eye examination rates by race and ethnicity. A study of 2002-2013 MEPS data also found there was no association between race and ethnicity and receipt of eye examination in a model adjusting for age, sex education, insurance status, economic status, diabetes care measures, and vision and general health measures (Tran et al., 2017). However, our results differ from those reported in Chen et al.'s study (2014). In Chen et al.'s (2014) study of 2001-2010 MEPS data, their adjusted model was most comparable to our fully adjusted model in that it adjusted for eight out of nine of our predisposing, enabling, and need factors (did not adjust for duration of diabetes). In their adjusted model, race and ethnicity remained significantly associated with receipt of eye examination; non-Hispanic blacks and Hispanics were more likely to obtain an eye examination than non-Hispanic whites.

Medicaid Expansion Analyses

There have been limited prior studies examining the effects of the ACA on changes in eye examination rates. In this study, Medicaid expansion was not associated with changes in eye examination rates in any of the multivariable logistic regression analyses. In Chen et al.'s (2020) quasi-experimental study using 2009-2017 BRFSS data, results of DiD analysis (adjusted for age, sex, and race) revealed that Medicaid expansion was associated with a significant increase in eye examination rates for the 2014-2015 period but was no longer associated with changes in eye examination rates for the cumulative study periods of 2014-2016 and 2014-2017. The lack of association between Medicaid expansion and changes in eye examination rates could be influenced by changes in provider availability. With improvements in insurance access, there may not be enough eye care specialist available to meet the demand of the increased number of newly insured patients requiring eye examinations. Recent studies reported increased difficulty of obtaining a specialist appointment in 2016 compared to 2014 or 2015 (Sommers et al., 2017) and significantly longer wait times for low-income adults in expansion states (Miller & Wherry, 2017). Limited eye care specialist availability is plausible considering that 60.7% of counties in the U.S. are in the lowest two quartiles for ophthalmologist and optometrist availability (Gibson, 2015).

Study Limitations

This study had several limitations. First, the MEPS diabetes care survey only collects information on the dilated eye examinations but does not collect information on other forms of diabetic retinopathy screening such as validated retinal photography used in telemedicine. However, dilated eye examination is still considered the gold standard for diabetic retinopathy screening, so the rates should be most relevant to quality of care for diabetes (ADA, 2019). Second, due to the phrasing of the outcome question which asks responders if they have had a dilated eye examination within the survey year, it is possible to underestimate the prevalence of dilated eye examination. Respondents might not have obtained their annual eye examination at the time that the MEPS interview was conducted. Therefore, cases could be missed if the respondent obtained an eye examination following the MEPS interview. Third, MEPS does not include a measure for whether respondents have prediabetes or undiagnosed diabetes. As of 2018, 7.3 million adults (age≥18years) in the U.S. had undiagnosed diabetes and 88 million adults had prediabetes (CDC, 2020a). Therefore, underreporting of diabetes prevalence is possible. Fourth, if a large proportion of the study respondents enrolled in Medicaid prior to expansion, then the effect of Medicaid expansion might be underestimated. We partially controlled for this effect by including non-expansion states that likely had similar cross-sections of survey respondents and by including insurance status as a control variable in adjusted models.

Public Health Implications

Although there are effective treatments available to prevent and even reverse vision loss from diabetic retinopathy, it still remains one of the leading causes of preventable blindness in the U.S. (CDC, 2018; Cheung, Mitchell, & Wong, 2010; Leasher et al., 2016). It is important that diabetic retinopathy screening programs are tailored to target those at highest risk and who are least likely to obtain screening. In order to create a successful screening program, it is important to understand the factors that influence whether an individual obtains screening. This study provides evidence that trends in dilated eye examination rates remained relatively stable; racial and ethnic disparities in eye examination rates are no longer apparent after controlling for predisposing, enabling, and need factors, and Medicaid expansion was not associated with changes in eye examination rates.

The U.S. Department of Health and Human Services' Healthy People goals of vision includes increasing the proportion of people who have an annual dilated eye examination to 58.7% for 2020 and 67.6% for 2030 (ODPHP, 2020b, 2020c). Our study found that overall rates were 64-66% implying that the adult diabetes population has consistently met the 2020 goal. Although not significant, our study did find a slight downward trend in rates, so whether eye examination rates will meet the 2030 goal over the next decade is uncertain.

Although lack of health insurance has been identified as a major barrier to individuals obtaining necessary medical care including diabetic retinopathy screenings (Ellish, Royak-Schaler, & Passmore et al., 2007; Lu et al., 2016; Owsley et al., 2006; Paz et al., 2006; Shi et al., 2014; Walker et al., 1997), our analysis examining the role of Medicaid expansion on eye examination rates found no significant differences in eye examination rates between individuals residing in an expansion versus non-expansion states suggesting that increases in insurance access alone may not be sufficient in improving dilated eye examination rates. Our results based on fully adjusted DiD models showed that several of the predisposing, need, and enabling factors (i.e., age, education, marital status, has usual provider, insurance status, takes insulin, and duration of diabetes) were related to receipt of eye examination. Thus, future research on policies or programs aimed at addressing other influencing factors may be warranted to improve dilated eye examination rates.

For instance, health literacy regarding the need for a dilated eye examination was identified as a major barrier of diabetic retinopathy screening (Graham-Rowe et al., 2018; Liu & Swearingen, 2017; Piyasenya et al., 2019; Lindenmeyer et al., 2014; Srinivasan et al., 2017). The U.S. Department of Health and Human Services defines health literacy as “the degree to which individuals have the capacity to obtain, process, and understand basic health information needed to make appropriate health decisions” (Koh, 2010; ODPHP, 2020d). Persons with adequate health literacy are more likely to take responsibility for their health and for their family’s health (ODPHP, 2020d). Those at risks for reduced levels of health literacy include individuals with lower education levels and racial and ethnic minorities (Cutilli & Bennet, 2009; Fathy et al., 2016; Kutner et al., 2006). In a study using data from the 2003

National Assessment of Adult Literacy (NAAL), almost half of adults who did not graduate from high school had low health literacy (Kutner et al., 2006). Our study saw that a significantly higher proportion of Hispanics compared to non-Hispanic whites had <12 years of education (45% vs 13%, $p<.001$) (see **Appendix 9**). Previous research supports that Hispanics have the highest high school dropout rates followed by blacks and whites (Kena et al., 2015). Therefore, it is probable that the difference in education level may be associated with the respondents' level of health literacy regarding diabetes care and thus, contribute to the respondents' non-adherence to diabetic retinopathy screening guidelines. Interventions aimed at improving patient knowledge regarding diabetic retinopathy and screening should be tailored to match different levels of education.

In addition to low health literacy, the lack of a health care provider's recommendation for eye screening has also been identified as a barrier of diabetic retinopathy screening (Dervan et al., 2008; Kashim, Newton, & Ojo, 2018; Van Eijk et al., 2012). Primary care providers play a vital role in diabetic eye care as they can educate, recommend, and refer patients to eye specialist for screening (Liu & Swearingen, 2017). Primary care providers do not directly perform diabetic retinopathy screening but may have greater access to patients with diabetes than do eye care providers because at least 90% of US patients diagnosed with diabetes are treated by primary care physicians (Davidson, 2010; Liu & Swearingen, 2017). Therefore, they can influence more patients with diabetes to have eye screening through their recommendation. However, limited access to a usual primary care provider can reduce opportunities for screening recommendations. Our study found that a greater proportion of persons with a usual provider had an eye examination compared to persons without a usual provider (66.3% vs 54.5%, $p=<.001$; Table 4.2). Interventions should target improving access to primary care providers for vulnerable populations that will benefit most from diabetic retinopathy screening. Practices to improve access to care include addressing illiteracy and low health literacy among patients, identifying cost-effective resources for patients, and helping patients find the least expensive options for transportation, insurance, and medication (Toscos et al., 2018).

Opportunities for Future Research

Although screening as met the 2020 target and appears to remain stable over the past decade, improving screening rates continues to be a priority objective of 2030 healthy people. Improving screening rates will require more creative methods for health care delivery as access to care continues to be a barrier for many. Access to eye care specialists has been identified as a barrier of diabetic retinopathy screening (Lindenmeyer et al., 2014; Liu & Swearingen, 2017) and is also often limited by geographic, economic, cultural, educational, and other factors (Cavallerano & Conlin, 2008; Hartnett, et al., 2005; Gower et al., 2013). Studies have shown that residents in areas with a low density of eye care professionals are less likely to have an annual eye examination (Chou et al., 2012; Resnikoff et al., 2012). A study of BRFSS data linked to the Area Resource File found that individuals residing in counties with less than 20 eye care professionals/100,000 people were less likely to report having had a dilated eye examination in the past year than those with 20 or more ECPs/100,000 people (Chou et al., 2012). Further, analyses of data from the 2011 Area Health Resources File demonstrated that 24.0% of the 3143 US counties had no ophthalmologists or optometrists (Gibson, 2015) and many of these counties are rural areas where long travel distances have been shown to negatively affect adherence to diabetic eye screening (Chen et al., 2020; Liu et al., 2018) supporting the notion that the distribution of optometrists in the US is not conducive to the coverage of remote areas (Gupta et al., 2017).

Telemedicine screening for diabetic retinopathy has the potential to provide screening services to areas where optometrists or ophthalmologist are scarce, thus, enabling individuals who live in these areas to have greater access to diabetic retinopathy screening services (ADA, 2019, p. 129). This strategy involves digital retinal photography with remote reading by an eye specialist and is considered an appropriate alternative method for diabetic retinopathy screening (ADA, 2019, p. 129). Studies evaluating the United Kingdom's Diabetic Eye Screening Program (DESP), which uses telemedicine to enable broader coverage, have shown that the program was successful in increasing the annual uptake of diabetic eye screening (Public Health England, 2017; Scanlon, 2017; Sim et al., 2016). As telemedicine programs continue to evolve and expand, future studies should 1) examine the effects of telemedicine on uptake and adherence to diabetic retinopathy screening guidelines, particularly in vulnerable populations and areas with a low density of eye care specialists, 2) examine the costs-effectiveness of the telemedicine approach compared to the traditional optometry/ophthalmology approach, and 3) how effective is it in detecting and preventing adverse eye outcomes.

Prior studies and the present study used survey data to examine the association of Medicaid expansion on changes in eye examination rates in low-income adults with diabetes. However, the use of other data sources (e.g., administrative records) to examine this topic would enhance this body of research. Future research could examine changes in visits to eye care specialist, changes in eye care-related provider visits, costs and reimbursements in diabetic adults residing in expansion versus non-expansion states

Conclusions

Diabetic retinopathy is a treatable condition if caught early, yet many of individuals forego screening, which can lead to the development of vision loss and/or blindness. This study provided critical insight into the present trends (8-year avg rate: 65.0 %) in diabetic retinopathy screening that have remained relatively stable across 2010-2017, how those trends measure up to the national vision care targets of 58.7% (2020) and 67.6% (2030), and seemingly no differences in diabetic retinopathy screening between non-Hispanic whites, non-Hispanic blacks, and Hispanics when adjusting for predisposing (age, sex, education, marital status), enabling (economic status, insurance status, usual provider), and need factors (insulin use, duration of diabetes). Additionally, it provided insight on the effects of Medicaid expansion on eye examinations in diabetic adults living below 138% of the FPL. Based on the study's findings, insurance coverage may be necessary to access regular eye care among diabetic patients, but it may not be sufficient. Continued advancement in the delivery of screening for diabetic patients will be necessary to improve their overall eye care.

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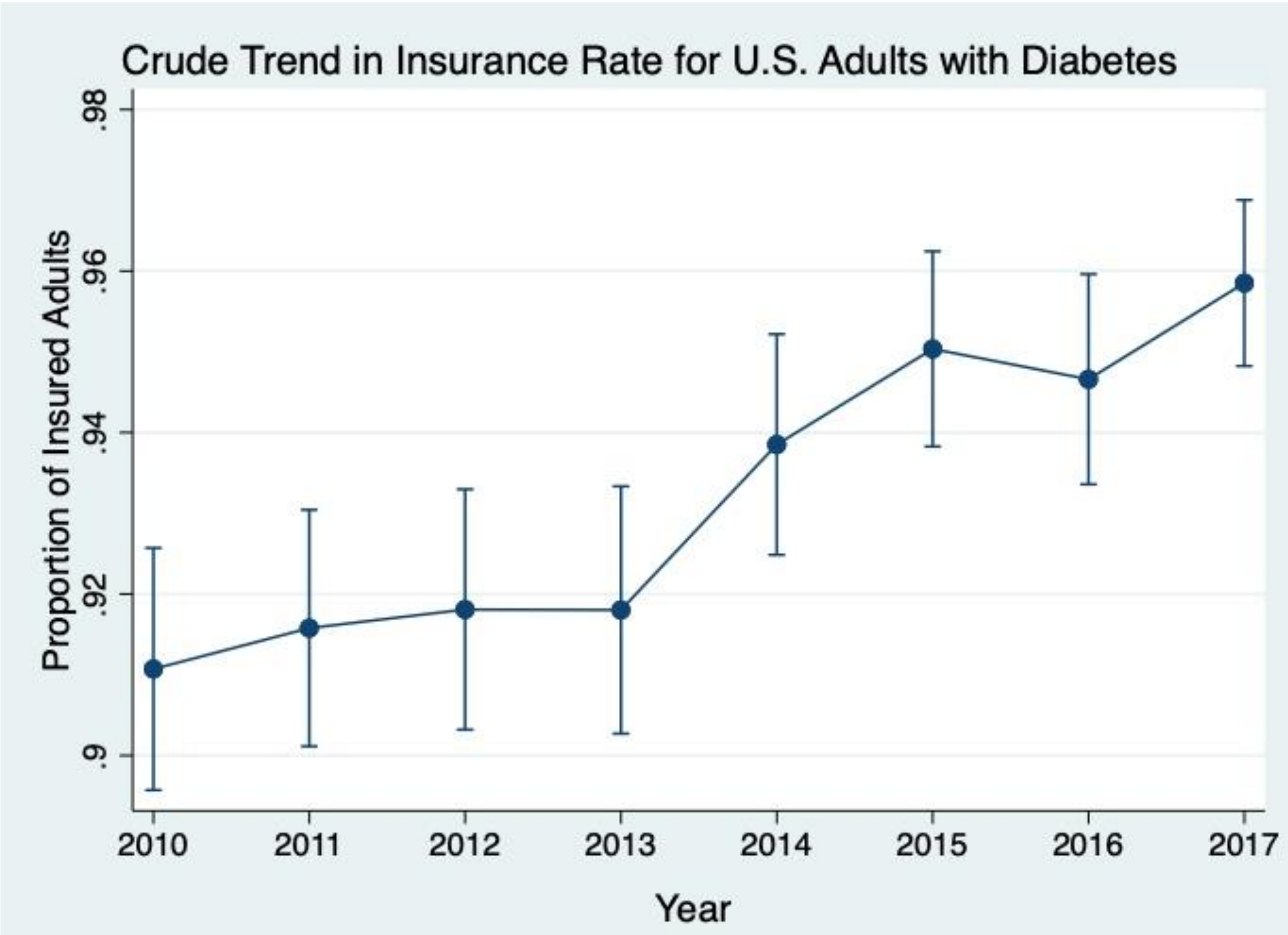
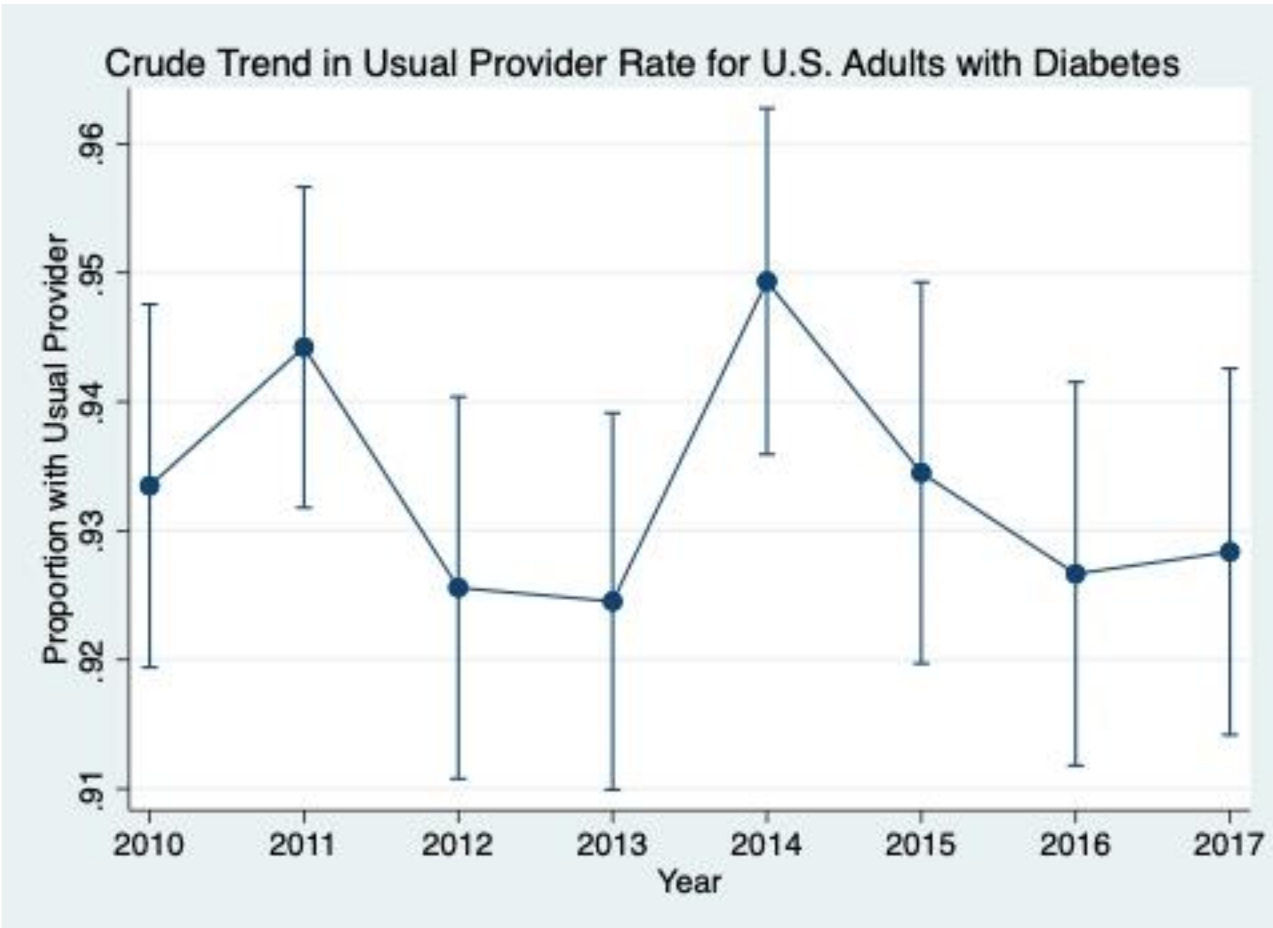
APPENDICES

A Crude Trend in Insurance Rate among U.S. Adults with Diabetes



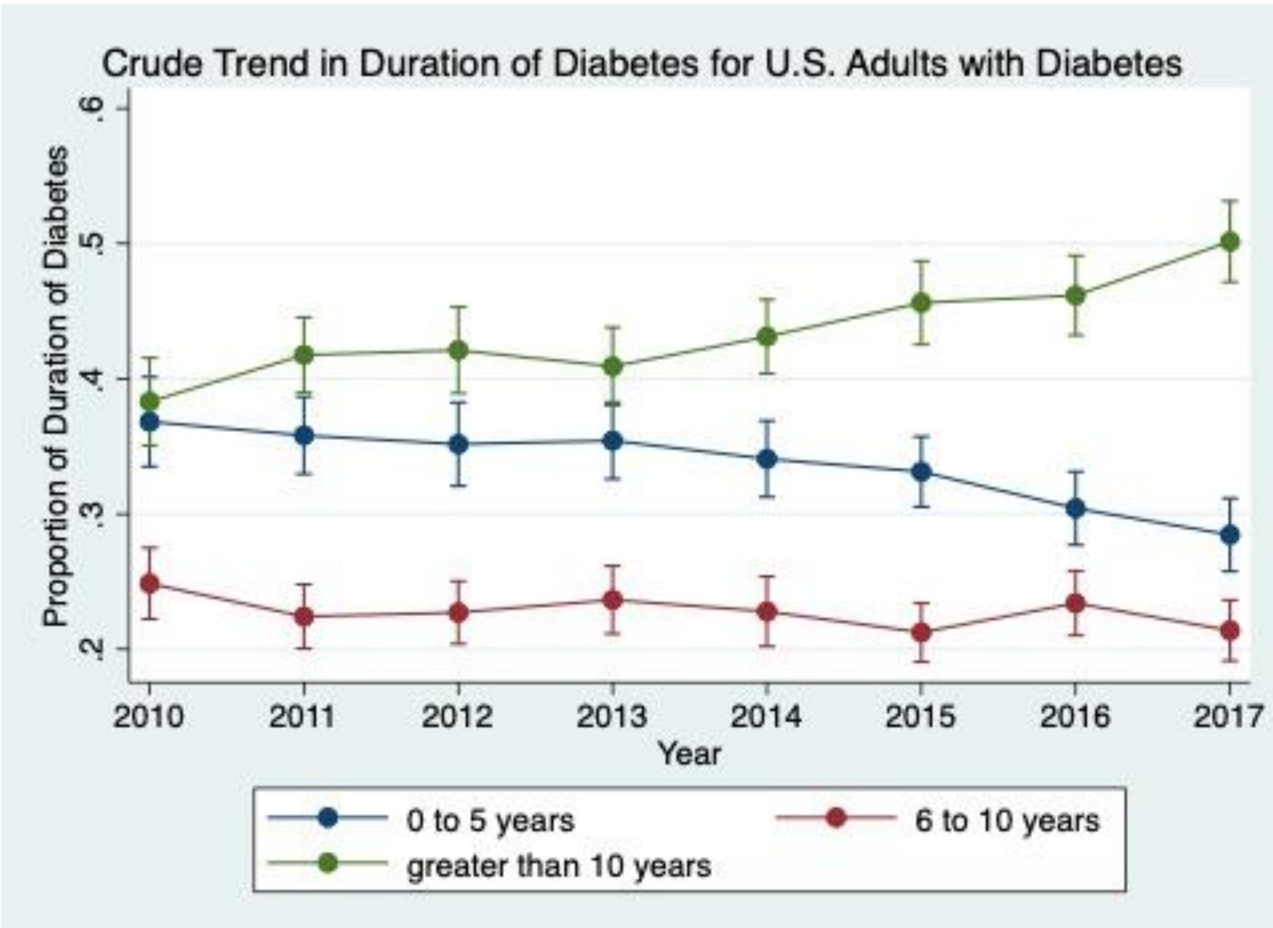
Appendix A. MEPS 2010-2017. Error bars represent 95% confidence intervals.

B Crude Trend in Usual Provider for U.S. Adults with Diabetes



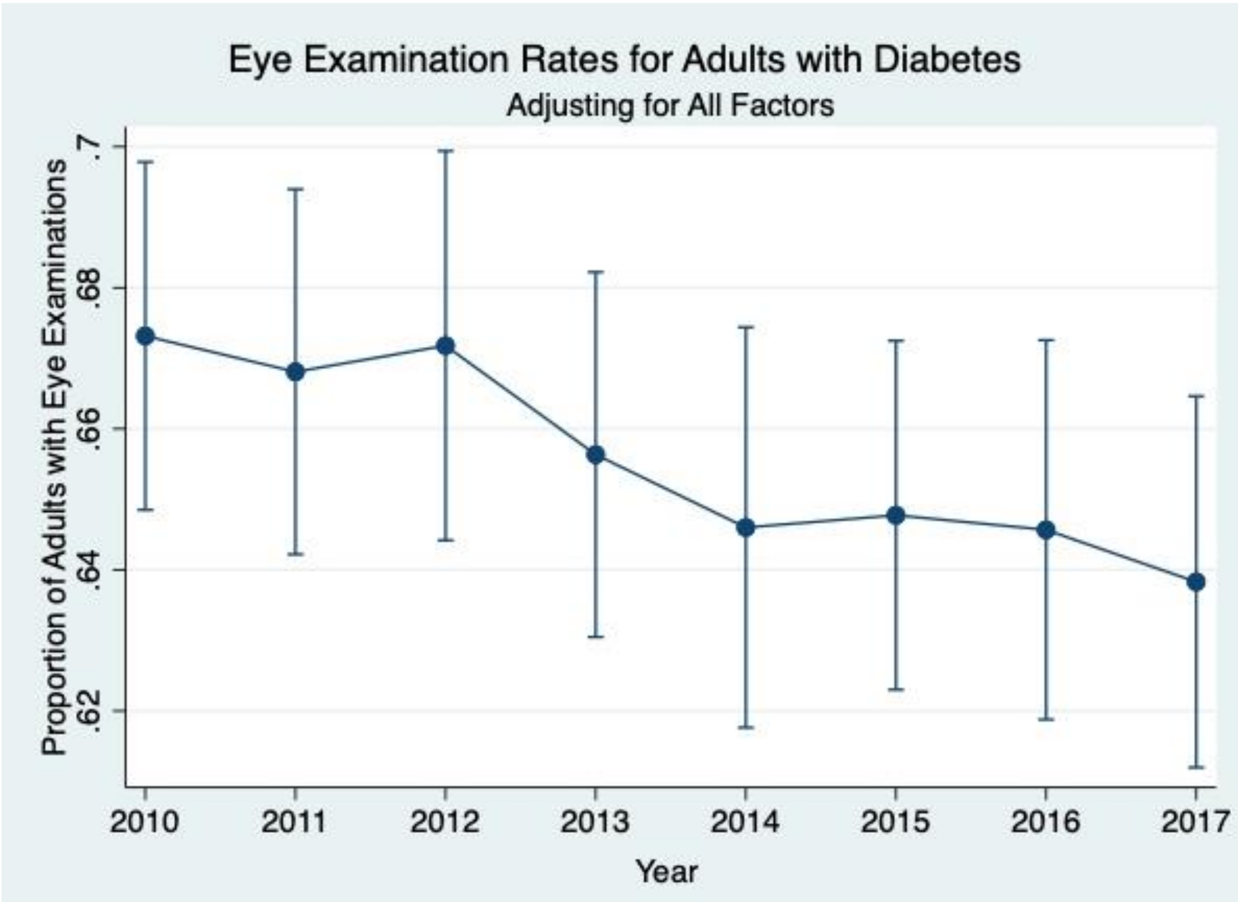
Appendix B. MEPS 2010-2017. Error bars represent 95% confidence intervals.

C Crude Trend in Duration of Diabetes for U.S. Adults with Diabetes



Appendix C. MEPS 2010-2017. Error bars represent 95% confidence intervals.

D Eye Examination Rates for U.S. Adults with Diabetes



Appendix D. Adjusted trend in eye examinations for U.S. adults (age ≥18) with diabetes: MEPS 2010-2017. Error bars represent 95% confidence intervals.

E Adjusted Model with Race and Ethnicity*Insurance Status Interaction Term

	AAP	95% CI	AME	p-value
Race and ethnicity				
NHW	65.5	64.0-67.0	Ref.	Ref.
NHB	65.6	63.8-67.5	0.1	0.904
Hispanic	64.7	62.3-67.0	-0.8	0.583
Insurance status				
Uninsured	46.8	42.1-51.4	Ref.	Ref.
Insured	66.7	65.5-67.9	19.9	<.001
NHW*Insurance Status				
NHW*Uninsured	44.4	38.1-50.6	Ref.	Ref.
NHW*Insured	67.0	65.4-68.6	22.6	<.001
NHB*Uninsured	50.6	44.0-57.1	Ref.	Ref.
NHB*Insured	66.7	64.8-68.7	16.2	<.001
Hispanic*Uninsured	53.0	48.0-58.0	Ref.	Ref.
Hispanic*Insured	65.6	63.1-68.0	12.5	<.001

Note. All models were adjusted for year, age, sex, education, marital status, insurance status, economic status, have usual source of care, insulin use, and duration of diabetes. AAP, average adjusted prediction; AME, average marginal effects NHW, non-Hispanic white; NHB, non-Hispanic black; CI, confidence interval; ref, reference

F Adjusted Model with Race and Ethnicity*Economic Status Interaction Term

	AAP	95% CI	AME	p-value
Race and ethnicity				
NHW	65.6	63.9-66.9	Ref.	Ref.
NHB	65.5	63.5-67.5	0.1	0.967
Hispanic	64.6	62.2-66.9	-0.1	0.546
Economic status				
<138% FPL	62.3	60.3-64.3	Ref.	Ref.
≥138% FPL	66.2	64.9-67.5	3.9	<.001
NHW*Economic status				
NHW*<138% FPL	61.1	58.4-63.8	Ref.	Ref.
NHW*≥138% FPL	66.8	65.1-68.5	5.6	<.001
NHB*<138% FPL	63.9	60.9-66.8	Ref.	Ref.
NHB*≥138% FPL	66.0	63.5-68.5	2.2	0.273
Hispanic*<138% FPL	65.5	62.4-68.5	Ref.	Ref.
Hispanic*≥138% FPL	64.3	61.5-67.1	-1.2	0.543

Note. All models were adjusted for year, age, sex, education, marital status, insurance status, economic status, have usual source of care, insulin use, and duration of diabetes. AAP, average adjusted prediction; AME, average marginal effects NHW, non-Hispanic white; NHB, non-Hispanic black; CI, confidence interval; ref, reference

G Likelihood Ratio Tests

	Degrees of Freedom	Chi-square	p-value
Trend Analysis			
Full vs Predisposing	6	553.12	<.001
Full vs Enabling	8	644.64	<.001
Full vs Need	8	782.42	<.001
Medicaid Expansion Analysis			
Full vs Predisposing	5	197.27	<.001
Full vs Enabling	8	200.80	<.001
Full vs Need	7	199.98	<.001

H Sensitivity Analyses

	AOR	95% CI	P-value
Treatment Effects			
Model 1			
Years since expansion	1.1	0.9-1.3	0.263
Model 2			
Expanded-1-year lag	1.1	0.8-1.6	0.508
Model 3			
Expanded-2-year lag	1.3	0.9-1.8	0.099

Note. Reference category for each treatment variable was no expansion. All models were adjusted for age, sex, race and ethnicity, education, marital status, insurance status, have usual source of care, insulin use, duration of diabetes and state and year fixed effects. AOR, adjusted odds ration; CI, confidence interval.

I Distribution of Population Characteristics by Race and Ethnicity

	Trend Sample (n=14,380)				Medicaid Sample (n=4,790)			
	NH whites, %	NH-blacks, %	Hispanics, %	p-value	NH whites, %	NH-blacks, %	Hispanics, %	p-value
Age				<.001				<.001
18 to 44 years	9.4	15.3	17.9		12.2	16.8	19.7	
45 to 64 years	43.4	48.4	49.0		44.0	47.7	45.6	
>=65 years	47.2	36.3	33.1		43.8	35.5	34.7	
Sex				<.001				0.027
Men	51.8	42.4	47.5		39.1	34.4	41.2	
Women	48.2	57.6	52.5		60.9	65.6	58.8	
Education				<.001				<.001
≥12 years	86.5	80.1	54.3		72.1	68.7	38.5	
<12 years	13.5	19.9	45.7		27.9	31.3	61.5	
Marital Status				<.001				<.001
Single	39.4	60.6	43.6		33.3	21.5	45.6	
Married/partnered	60.6	39.4	56.4		66.7	78.5	54.4	
Economic status				<.001				
<138% FPL	17.2	32.8	35.9		n/a	n/a	n/a	
≥138% FPL	82.8	67.2	65.1		n/a	n/a	n/a	
Has Usual Provider				<.001				<.001
No	5.4	6.9	88.5		8.4	8.1	12.5	
Yes	94.6	93.1	11..5		91.5	91.9	87.5	
Insurance Status				<.001				<.001
Uninsured	4.4	6.6	16.3		6.9	10.0	21.6	
Insured	95.6	93.4	83.7		93.1	90.0	78.4	
Takes insulin				<.001				<.001
No	69.5	68.3	68.9		64.0	61.5	65.0	
Yes	30.5	31.7	31.1		36.0	38.5	35.0	
Diabetes Duration				<.001				<.001
0-5 years	33.2	33.4	34.9		32.0	32.0	32.7	
6-10 years	22.6	22.8	23.2		21.7	21.7	21.6	
>10 years	44.2	43.8	41.9		46.3	46.3	45.7	

Note. P<0.05 considered statistically significant. N/a, not applicable; NH, non-Hispanic; FPL, federal poverty level